# HEALTH DISPARITY AND THE BUILT ENVIRONMENT: SPATIAL DISPARITY AND ENVIRONMENTAL CORRELATES OF HEALTH STATUS, OBESITY, AND HEALTH DISPARITY

A Dissertation

by

EUN JUNG KIM

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2007

Major Subject: Urban and Regional Sciences

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# ABSTRACT

Health Disparity and the Built Environment: Spatial Disparity and Environmental Correlates of Health Status, Obesity, and Health Disparity. (August 2007)

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Increasing evidence suggests that the environment is related to many public health challenges. Unequal distributions of services and resources needed for healthy lifestyles may contribute to increasing levels of health disparity. However, empirical studies are not sufficient to understand the relationship between health disparity and the built environment.

This dissertation examines how health disparity are associated with the built environment and if the environmental conditions that support physical activity and healthy diet are associated with lower health disparity. This research uses a multi-disciplinary approach, drawing from urban planning, regional economics and public health.

The data came from the Behavioral Risk Factor Surveillance System, and the GIS derived environmental data and the 608-respondent survey data from a larger study conducted in urbanized King County, Washington. Health disparity was measured with the Gini-coefficient, and health status and obesity were used as indicators of health. Hot spot analysis was used to identify the spatial aggregations of high health disparity, and multiple regression models identified the environmental correlates of health disparity.

The overall trend showed that disparity has increased in most states in the US over the past decade and the southern states showed the highest disparity levels. Strong spatial autocorrelations were found for disparities, indicating that disparity levels are not equally distributed across different geographic areas. From the multivariate analyses estimating disparity levels, spatial regression models significantly improved the overall model fit compared to the ordinary least-square models. Areas with more supportive built environments for physical activity had lower health disparities, including proximity to downtown (+) and access to parks (+), day care centers (+), offices (+), schools (+), theaters (+), big box shopping centers (-), and libraries (-). Overall results showed that the built environment, compared to the personal factors, was more strongly correlated with health disparities.

This study brings attention to the problem of health disparity in the US, and provides evidence supporting the existence of spatial disparity in the environmental support for a healthy lifestyle. Further research is needed to better understand environmental and socioeconomic conditions associated with health disparity among more diverse population groups and in different environmental settings.

# DEDICATION

To my parents

and

my heavenly father, God

## ACKNOWLEDGEMENTS

This dissertation would not have been possible, nor could it have been completed, without the support of many special people. I would like to thank Dr. Chanam Lee who not only served as my committee chair, but also encouraged and challenged me throughout my academic program. Her scholarly passion and diligence enabled me to develop this dissertation from an initial idea all the way to completion. I am grateful to my committee members, Dr. Donald A. Sweeney, Dr. Cecilia Giusti, and Dr. Daniel Z. Sui for their useful and perceptive comments on my dissertation work.

I am very pleased to thank my parents for their invaluable encouragement and useful advice. I would not have even tried to challenge myself and could not have completed this work without their endless love. I would also like to express my gratitude to my sisters, brothers-in-law, nephews, and nieces for their generous support and love. They always comforted me with humor to help me enjoy life and to not get homesick.

My appreciation must also go to my spiritual family in my church in Korea. They always prayed for me not to struggle against circumstance and to go forward with wisdom at every step of my doctoral program.

I dedicate this dissertation to my heavenly father, God. I would not have been able to write a single word without His support and guidance. It is my greatest hope that my participation will contribute in some way to the advancement of the world and His nation.

# TABLE OF CONTENTS

Page

CHAPTER Page

CHAPTER Page

# LIST OF FIGURES

Page

# LIST OF TABLES

Page

Page

# CHAPTER I

# INTRODUCTION

## 1.1. Background

The issue of regional inequalities, especially in income and job opportunities, has long been an important subject of research in welfare economics, sociology, and urban planning (Baer, 1964; Eckhaus, 1961; Lasuen, 1962; Preston and McLafferty, 1999). Inequalities in health have emerged as one of the top public policy agendas as a growing body of evidence suggests that different sub-populations are exposed to different rates of disease incidences and mortalities. Recent movements in active living and obesity prevention also put forward the primary goal of the reduction or elimination of disparities in obesity and related health risks (US Department of Health and Human Services, 2000; Johnson et al., 2003). Previous empirical studies in health disparities have focused on comparisons between different sub-populations often defined by their socio-demographic factors such as race, gender, age, education, and income (Braveman and Gruskin, 2003). Few studies consider the spatial distributions and environmental attributes associated with health disparities.

Increasing evidence suggests that the environment is a significant contributor to many public health challenges such as obesity, type II diabetes, cardiovascular and respiratory diseases, and depression (Poston and Foreyt, 1999; Hill et al., 2003; Jackson

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This dissertation follows the style of *Journal of the American Planning Association*.

and Kochtitzky, 2001). Further, disparities in health are believed to be associated with the unequal distribution of resources and opportunities in the environment such as access to health care, physical activity and exercise facilities, and healthy food (Gordon-Larsen et al., 2006). However, empirical studies are insufficient for understanding the extent and magnitude of health disparities in the United States. Methods for measuring health disparity have been limited. Literature from regional science, which addresses inequalities in job opportunities and income, offers useful tools for measuring health disparity that are both effective and efficient.

### 1.2. Specific Aims

This study: (1) reviews the literature from public health and regional science that deals with disparities, especially on the methods for measuring disparity, to put forward a multidisciplinary approach for studying health disparity; (2) examines the magnitude and the trends of health disparity in the US based on the results from the literature review to bring attention to the problem of health disparity in the US; (3) investigates the effects of the built environment on health status, obesity (through the Body Mass Index or BMI), and health disparity using multiple regression models to understand how detailed attributes of the built environment are significantly associated with health status, obesity, and health disparity after controlling for socio-demographic confounders ; and (4) provides policy recommendations for federal and local planners to better manage the built environment for reducing health disparity, increasing health status, and reducing obesity.

The specific aims of this dissertation are as follows:

Aim One is to examine the magnitude and the trends of health disparity in the US by state, between 1995 and 2004.

Aim Two is to analyze spatial patterns of areas with concentrated disparity and to identify significant environment factors which contribute to the creation of these areas.

Aim Three is to identify built environmental correlates of health status, obesity, and health disparity using bivariate correlation analysis at the zip code level and multiple regression models at the individual level.

Aim Four is to suggest policies for increasing health status, reducing obesity, and reducing health disparity.

**1.3. Significance**

This study provides valuable information for the federal government and health professionals on the status and historic trends of health disparities. It offers insight into how to manage the built environment to help reduce health disparities. By understanding the factors that influence obesity, health status, and health disparity, local and regional planners can set appropriate policy programs to reduce health disparity (e.g. land use planning, expenditure on infrastructure, and development regulations).

This dissertation has the following theoretical and practical significance. First, it considers the concept of regional income disparity and health disparity synthetically, both of which have traditionally remained separate. Regional income disparity is one of traditional research topics in urban economics and regional science and its strengths include advanced methodologies and an extensive body of existing empirical studies accumulated over the past five decades. In contrast, health disparity research is an emerging research topic in public health and urban planning; although growing, the existing literature in this area of research is still limited and most studies have remained descriptive, simply comparing different sub-groups based on the different socio-demographic background. Thus, this dissertation takes an interdisciplinary approach from urban economics and regional science to measure and analyze health disparity in order to offer more valid, empirical insights into this major health problem.

Second, this study contributes to a better understanding of the specific built environmental variables that are associated with health disparity, health status, and obesity by proposing a conceptual framework based on theoretical foundations which incorporate ecological theory, general systems theory, the behavioral model of environment, and previous literature. Ecological theory is employed as a key theoretical basis while general systems theory and a behavioral model of environment contribute to the conceptualization of this dissertation research. The developed conceptual framework serves as a basis for this multidisciplinary research, and it brings together three major research fields: urban design and planning, public health and epidemiology, and regional science.

Third, this research helps fill the gap in the health disparity-environment relationship literature by considering detailed and objectively measured built environmental variables and by employing advanced analytical techniques. This research considers both objective and subjective measures of the built environment through survey and GIS measurements. These detailed and disaggregated measures help identify precise links between the built environment and health disparity. Moreover, it employs rigorous, new analytical methods that have not been used in previous empirical studies in this area of research. These new methods include Gini coefficient, hot spot analysis, and a spatial regression model.

### 1.4. Dissertation Structure

This dissertation consists of five chapters. This chapter, Chapter I, provides the introduction and overview to the research.

Chapter II reviews the literature related to the topics of the dissertation in order to form an understanding of the conception of health disparity and the built environment. The first section of the chapter briefly introduces the importance of the review of the health disparity issue; the second section looks into the current status of knowledge including the definition, indicators and measurement, relationship with regional income disparity, and the role of the built environment on health disparity. The third section proposes a multidisciplinary research framework for better identifying the correlates of the built environment on health disparity through introducing obesity, in addition to perceived health status, as disparity indicators. The fourth section synthetically describes the conceptual and empirical linkages between health disparity and the built environment. Finally, the last sub-section summarizes the overall findings from the literature review and the estimated importance of the proposed conceptual framework.

Chapter III explains the methods used in this dissertation. It builds a research design and hypotheses for the four aims of the study based on the proposed conceptual framework at end of the first sub-section. The second and third sections describe the study area and the data collection methods, specific measurements, and variables. The fourth section explains the data analysis procedure used to develop efficient and effective models.

Chapter IV reports the findings of this dissertation study. It consists of four sub-sections based on the classification of the specific aims. The first, second, and third sub-sections are the results of aims one, two, and three, respectively. Section 4.1 includes overall health disparity trends, regional differences in disparity and disparity trends, the top ten states with the highest disparity, and the correlations between disparity and selected SES variables in the US by state between 1995 and 2004. Section 4.2 is an exploratory analysis which provides a snapshot of geography in health disparity through hot spots. Section 4.3 splits into two parts (e.g. zip code- and individual- level analyses). Sections 4.3.1 and 4.3.2 cover the built environmental correlates of health disparity using bivariate correlation analysis at the zip code level and multiple regression models at the individual level, respectively.

Chapter V is the conclusion and summarizes the key findings of this dissertation. It also suggests policy implications and recommendations for reducing obesity, increasing health status, and alleviating health disparity. This chapter also includes a discussion, limitation of this research, and future study directions.

# CHAPTER II

# LITERATURE REVIEW

## 2.1. Introduction

This dissertation addresses two of the most important issues that affect every member and aspect of our society: health and social equity. Both issues are significant at all spatial levels, from the individual, the national, and the international levels. Inequalities in health, also known as health disparities, have emerged as a top research and policy agenda (e.g. World Bank, Robert Wood Johnson Foundation, Pan American Health Organization, and US Department of Health and Human Services). A growing body of evidence suggests that different sub-populations are exposed to different rates of disease and mortality. Recent movements in active living and obesity prevention also propose a reduction or elimination of disparities in obesity and health related risks as one of their primary goals.

Several organizations, such as the World Bank and the US Department of Health and Human Services (DHHS), initiated research on health disparity looking to find the causes and to propose policy solutions. “Elimination of health disparity” is a major goal presented in the Healthy People 2010 (2000) published by the US DHHS. An example of a state-level effort is by the California Campaign to Eliminate Racial and Ethnic Disparities in Health, called “Health for All: California’s Strategic Approach to Eliminating Racial and Ethnic Health Disparity” (Johnson et al., 2003). Building onto the current momentum of these initiatives, this research explored the current status of knowledge in understanding and measuring health disparity in relationship to the built environment. This paper reviewed the existing literature from multiple disciplines and identified the gaps in the current empirical knowledge. Literature from regional disparity study offers new insights into the theories and measurements useful to health disparity research.

In addition to a review of the empirical literature on the built environment-health disparity research, theories used to build the theoretical frameworks of this dissertation are also reviewed. This chapter reviews general and detailed theories which support the multidisciplinary approach. It investigates general systems theory, ecological theory, and the behavioral model of environment.

## 2.2. Health Disparity: Current Status

### 2.2.1. Definition

Even though the term “health disparity” is widely used in public health literature, there is no single definition for the term that everyone agrees upon; consequently, differences in meaning have lead to confusion and incommensurable results, so researchers have tried to sort through these diverse viewpoints. Carter-Pokras and Baquet (2002) evaluated eleven definitions derived from various sources such as Healthy People 2010 (2000), National Institutes of Health (2000), Institute of Medicine (2002), and Health Resources and Services Administration (2000). For example, Healthy People 2010 from the US DHHS defined health disparity as differences which occurred by gender, ethnicity, education, income, and disability in rural localities. The National

Institutes of Health said health disparities were differences in adverse health conditions such as mortality, morbidity, and prevalence among specific population groups. The Institute of Medicine defined health disparities as racial differences in health care quality. They concluded that the definition of health disparity is different according to the areas of health, population subgroups, etc. Braveman and Gruskin (2003) defined health disparity from the view of ethnicity; they explained it as the absence of inequalities in health that were systematically associated with social advantages and disadvantages such as gender, ethnicity, and religion.

### 2.2.2. Indicator and Measurement

One of the traditional topics in health disparity research is finding the indicators and measurement indices that are best suited for testing inequalities. By measuring inequality, it is possible to understand how well programs or policies promote social justice in health and how these strategies might be further developed and improved in the future. Clear and measurable definitions of health disparity are essential to the creation of effective policies. Many studies have tried to find optimal indicators and measurements, but the results are inconclusive. Examples of popular indicators and measurements of health disparity are shown in Table 2.1. Among the commonly used indicators of health are mortality, morbidity, self reported health status, and access to health care. Most of the other miscellaneous indicators can be lumped together with one of the more commonly used indicators.

Table 2.1. Selected Indicators and Measures of Health Disparity

| Indicator | Measurement | Source |
|---|---|---|
| Mortality | Age-standarized rate<br>Rate ratio<br>Gini coefficient<br>Excess mortality measure<br>Concentration coefficient<br>Index of dissimilarity (ID)<br>Absolute difference in death probabilities<br>Extremal quotients (EQ, maximum rate divided by minimum rate)<br>Coefficient of variation | Wagstaff et al. (1991)<br>Kunst, Groenhof, and Mackenbach (1998)<br>Gissler et al. (2000)<br>Turrell and Mathers (2001) |
| Morbidity including syphilis, gonorrhea, chlamydial infection, herpes, respiratory symptoms, asthma, obesity | Gini coefficient<br>Odds ratios<br>Agresti's alpha | Manor (1997)<br>Kerani et al.(2005) |
| Self-reported health | Concentration coefficient | Van Doorslaer et al. (1997, 2000)<br>Van Doorslaer and Koolman (2004) |
| Health care expenditures | Gini coefficient | Musgrove (1986) |
| Clinic utilization | Number/percentage of visits, divergency graph (Lorenz curve) | Kinman (1999) |
| Access to health care | Concentration coefficient, Atkinson | Waters (2000) |

Although most commonly used as a measure of income disparity, the Gini coefficient has also been used for health disparity (e.g. Musgrove, 1986; Kerani et al., 2005; Turrell and Mathers, 2001). The Gini coefficient is the most popular measurement for health disparity thus far in the available literature. Alternatively, several studies have used the Concentration coefficient, which was originally derived from the Gini coefficient and has also been simply called a modified version of the Gini coefficient (Van Doorslaer and Koolman, 2004; Van Doorslaer et al., 1997, 2000; Wagstaff et al., 1991; and Waters, 2000). When Waters used the Concentration coefficient to measure inequality (Waters, 2000), he compared the cumulative proportion of access to health care with the cumulative proportion of socio-economic status (SES) as measured by per-capita household expenditures. Since the concept of health is strongly associated with

SES, ordering by SES is more appropriate than using the simple cumulative proportion of the population.

The Gini coefficient has been considered the gold standard in regional science and urban economics so far, and is intuitively easy to understand and interpret. Thus, it is still the best measure for not only regional income disparity but also health disparity.

### 2.2.3. Relationship between Health Disparity and Regional Income Disparity

Recent studies have demonstrated that regional income disparity is related to health disparity. Van Doorslaer et al. (1997) found that self-reported health was unequally distributed across income levels among eight European countries and in the US. Since this was an international comparison, data for each country varied slightly, and most were collected in the 1980s. Van Doorslaer and Koolman (2004) have updated their previous study in thirteen European Union member countries by using a new data source (the European Community Household Panel, 1996) and method (interval group regression). Both studies concluded that health disparity had a positive correlation with income disparity, but the relationship appeared weaker than in previous research. Also, Van Doorslaer and Koolman (2004) revealed an interesting finding: not only income alone, but other factors such as education, labor force, status, and region of residence contributed to health disparities.

### 2.2.4. Role of Built Environment on Health Disparity

One of the ways to reduce health disparities is through changes in the built environment. For instance, greater access to supermarkets might be positively related to fruit and vegetable consumption (Morland, Wing, and Roux, 2002). An increase in play spaces near children's homes might have a positive effect on their physical activity (Sallis et al., 1993; Klesges et al., 1990). Housing quality has been closely connected to various kinds of morbidity (Geronimus, 2001) and psychological stress (Turrell and Mathers, 2001). The potentially significant role of the built environment on health disparity has promoted collaborative research between urban planning and design and public health fields. By understanding the factors that influence obesity, health status, and health disparity, local and regional planners can set appropriate policy programs to help reduce health disparity.

While it is believed that certain aspects of the built environment are associated with physical activity and health, the specific roles of the built environment in reducing health disparity are unclear at the moment.

## 2.3. Health Disparity and the Built Environment: Multidisciplinary Research Opportunities

### 2.3.1. Theoretical Framework

There are several theoretical frameworks used to explain the relationship between the built environment and obesity, physical activity, and diet pattern: social learning theory (Bandura, 1977), social cognitive theory (Bandura, 1986), social marketing theory (Andreasen, 1995), diffusion of innovations theory (Rogers, 1995), trans-disciplinary paradigm (King et al., 2002), ecological theory (Egger and Swinburn, 1997), the behavioral model of environments (Moudon and Lee, 2003), etc. From the more general view of forceful and pervasive paradigms in scholarly work, general systems theory is one of the most significant approaches. The theoretical underpinnings of this research are discussed as follows.

First, general systems theory offers an important framework for this study. It originated in biology and now is popular in almost every field of study. It was proposed by Ludwig von Bertalanffy (Bertalanffy, 1968), an Austrian biologist, in the 1940s, and further developed by Ross Ashby (Ashby, 1956). Systems theory emphasizes the complexity and interdependence of relationships among systems. A system is a set of objects or elements in interaction to achieve a specific goal. A system has subsystems which functions a part of larger system. Subsystems can work parallel to each other or in a series. All systems have five common elements: input, output, process, feedback, and goal (Gillies, 1982).

Historically, general systems theory was applied to philosophy, sociology, organizational theory, management, psychotherapy, economics, and so on. Even though its concept is ‘general,’ different systems have their own characteristics, perform their own process, and achieve their own unique goals. Uniqueness is possible through interconnections and interrelationships among system elements. General systems theory has also been implemented in community development plans to connect multiple components of life and livelihood in urban planning areas (Spruill, 2001).

According to the classification of elements of general systems theory, the components of this research can be arranged as follows. Inputs are the knowledge and understandings of health disparity, regional disparity, built environment, obesity, physical activity, and diet pattern. Through the understanding of relationships and interactions among these different knowledge areas, decreasing or eliminating health disparity, which is the goal of the system, can be accomplished.

Second, Egger and Swinburn (1997) proposed an ecological theory to understand and conceptualize obesity problems. The model is made up of mediators, moderators, and influential factors that have an effect on the equilibrium of levels of body fat. The levels of obesity and overweight depend not on a single factor, but on multiple interrelated elements at multiple levels, including physical activity, diet pattern, physiological impact, biology, behavior, and environment. Moreover, it considered environmental influences at multiple levels ranging from micro to macro levels. While its applicability to health disparity research has not been tested, the consideration of multi-level and multi-scale influences is useful for this proposed research.

A background of ecological theory supports the relationship between the built environment and physical activity. Because this paradigm is relatively simple and clear it is easy to understand. Moreover, it further considers the overall influences to facilitate a better understanding of the level of obesity, including physical activity, diet pattern, physiological impact, biology, behavior, and environment. In order to explain the relationship between the built environment and physical activity, the ecological theory supports sufficient determinants and their relationships. Moreover, it considers a macroscopic view of environmental influences, as well as at the micro level. McLeroy et al. (1988) proposed socio ecological model for health promotion. The model suggested that patterned behavior was determined by intrapersonal, interpersonal, institutional, community, and public policy factors. King (2002) also suggested not only consideration of the macro and micro scales of environments, but also the types of physical activity and extent of particular environmental condition which contribute positive and negative influences on physical activity. Thus, it suggests the possibility of public health interventions through the application of this theoretical framework. In addition, it includes several relevant environmental influences such as physical, economic, political, and socio-cultural perspectives to identify the energy balance of body and physical activity.

Third, the behavioral model of environment (BME) helps the identification and conceptualization of the built environment for physical activity, especially for walking and biking (Moudon and Lee, 2003). It consists of three elements, including Origin/Destination (OD), Route (R), and Area (A). Because these three aspects are highly correlated with an individual's travel decisions about walking and biking, it is useful for describing the relationship between the built environment and physical activity. For example, when taking a trip for recreational walking or biking, travel decisions are made by distance (OD), attractiveness of route (R), and attractiveness of destination (A). People usually consider all three components together.

While the precise application of this model requires extensive primary data collection efforts, it offers insight into the components of the built environment important for environment-physical activity research. This model is more relevant to understanding micro scale environmental factors.

This dissertation uses ecological theory as the primary model to frame the research, general systems theory to guide the conceptualization of the research in general, and BME to guide the operationalization of the built environment.

### 2.3.2. Obesity as an Indicator of Health Disparity

Obesity is a popular indicator of health status because, as opposed to being a single endogenous indicator, it is associated with many other health risks, including cardiovascular diseases, diabetes, mortality, and mental health. It has a direct relationship with physical activity and dietary habits, but has indirect, yet significant, relationships with the built and social environments. Obesity is considered a disease itself, and one of the leading health indicators according to Healthy People 2010 (2000) by the US Department of Health and Human Services and the New Zealand Ministry of Health (Ministry of Health, 2001). The National Institutes of Health (NIH) has focused on the prevention of obesity, especially among minority populations, as one of their top policy agendas. Goodman and colleagues (2001) used obesity as a physical health indicator for adolescents. While obesity is used popularly as an indicator of health itself, few studies have used obesity to measure health disparity (Table 2.1).

Disparities in obesity rates among different races and socio-economic statuses (SESs) have been documented with revealing findings. Several studies concluded that the obesity rates among African Americans were greater than that of Whites controlling for age and sex. (Crawford et al., 1994; Morrison et al., 1994; Troiano et al., 1995; Gordon-Larsen et al., 1999). Other studies showed that obesity was negatively associated with socio-economic status (Jeffery et al., 1989; Reijneveld, 1998; Sundquist and Johansson, 1998; Sundquist et al., 1999). In addition, obesity rates were closely associated with physical inactivity and high-fat and high-sugar food consumption (Poston and Foreyt, 1999; Chisholm et al., 1998; Price and Gottesman, 1991; Weinsier et al., 1998).

Since obesity is associated with many important health conditions, it becomes an effective indicator for health disparity. Moreover, the rapid growth of obesity rates means that it can be a good indicator for the long-term health surveillance purposes. However, obesity has rarely been used in experimental studies. Since weight and height are private and potentially sensitive issues, it is difficult to collect the data in an unbiased and non-intrusive manner, whereas data for mortality and morbidity rates are commonly available from the public secondary sources. Through an increasing number of empirical studies have involved primary data collection, Body Mass Index (BMI) computed by height and weight is becoming increasingly available for both local and national levels. For example, at the national level, the Behavioral Risk Factor Surveillance System (BRFSS) data are available, including BMI.

### 2.3.3. Multidisciplinary Approach

The concept of disparity can be viewed from two major perspectives. One is based on health, and the other is founded on a traditional view of regional income disparity, also sometimes called regional disparity. The latter is mostly concerned with general issues of regional science and urban economics. Although these issues are considered from different disciplinary perspectives, they deal with the common concept of disparity. Even though health disparity is the subject of a growing number of studies in recent years, regional disparity has a relatively longer history, including numerous empirical studies and advanced measurement methods. Therefore a review of regional income disparity will lead to easier ways of conceptualizing and measuring health disparity. By applying statistical and economic methodologies and measurements from regional income disparity to the areas of regional science and urban economics, a more empirical and precise interpretation of health disparity is possible.

This multi-disciplinary approach becomes even more important when obesity is used as an indicator of health disparity. Obesity has complex relationships with health science, active living, and urban design and planning. As an element of health science and active living, it is not only influenced by physical activity and diet patterns, but also directly affects both of these factors. Furthermore, the built environment, which is a subject of the urban design and planning field, affects obesity, physical activity, and diet patterns. Both physical activity and diet patterns are influenced by the built environment. The built environment is not only related to physical activity and diet, but also to forms and land uses that often determine the availability of and accessibility to certain foods and physical activity options. Although obesity, physical activity, and diet patterns are strong indicators of health disparity, researchers effectively ignore their important roles.

## 2.4. The Conceptual and Empirical Linkage between Health Disparity and the Built Environment

### 2.4.1. Conceptual Linkage

Based on the issues raised, the directions, and the guiding theories for the study proposed in Section 2.3, a conceptual framework for a multidisciplinary research agenda on health disparity is presented (Figure 2.1). The model shows that it is feasible to investigate the effects of the built environment on obesity, physical activity, and dietary patterns. It also includes an interdisciplinary approach between health disparity and regional disparity. In sum, the conceptual framework links three major disciplines: urban design and planning (the built environment), public health and epidemiology (obesity, physical activity, dietary patterns, and even health disparity), and regional disparity (regional science).

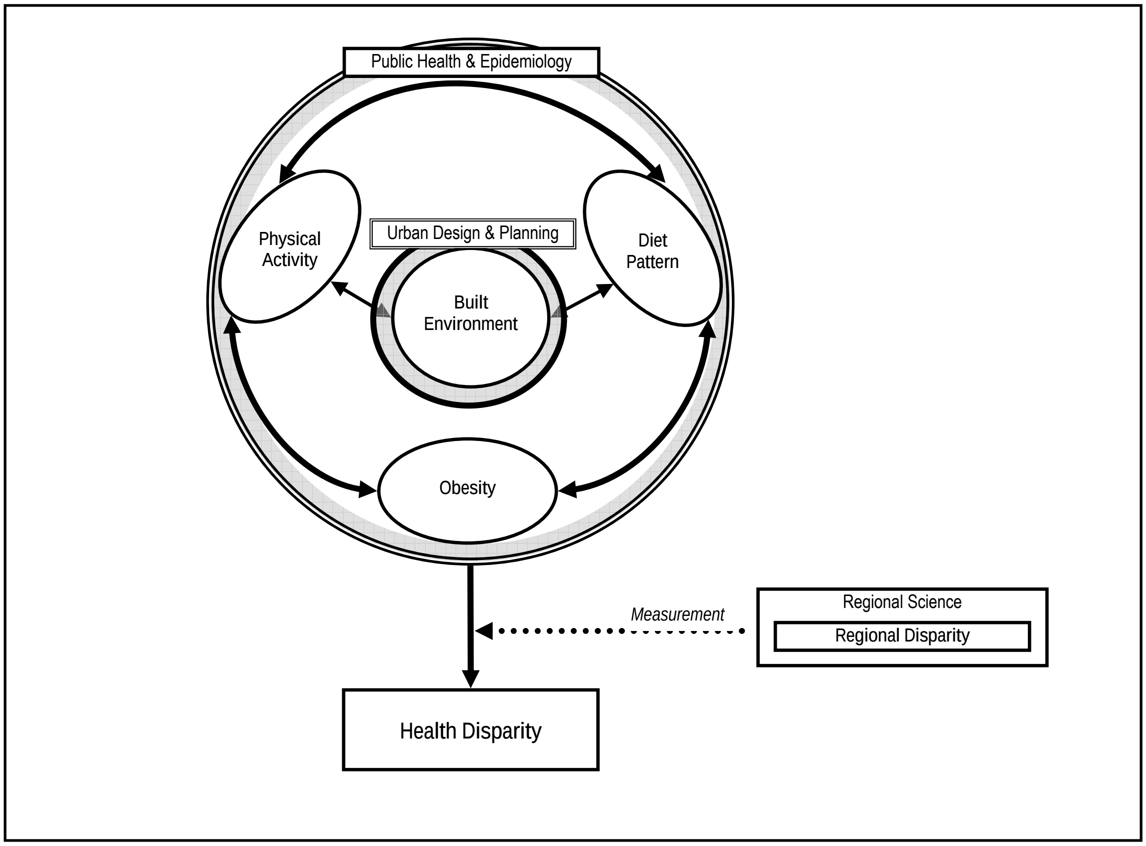


Figure 2.1. Multidisciplinary Conceptual Framework for Obesity-related Health Disparity Research

### 2.4.2. Empirical Linkage

Based on the conceptual framework, four areas are identified to assess the extent of empirical support for the model: (1) regional disparity, (2) the built environment and obesity, (3) the built environment and physical activity, and (4) the built environment and dietary patterns.

#### 2.4.2.1. Regional Disparity

The issue of regional inequality, especially regarding income and job opportunities, has long been an important research topic in welfare economics, sociology, and urban planning. Various urban spatial issues such as regional dualism, North-South dualism, and spatial mismatch are significant problems that are at least partly associated with regional disparity (Baer, 1964; Eckhaus, 1961; Lasuen, 1962; Preston and McLafferty, 1999). In spite of the rapid economic growth resulting from the Industrial Revolution and urbanization, the disparity in development patterns has continued and even worsened. Because the concentration of residents, commercial enterprises, and industries in metropolitan areas has become increasingly intensified, governments have implemented several decentralization policies such as strong development restrictions, incentives for firms to relocate, more government subsidies for industries outside urban centers, and more investments in rural areas (Brewis, 1969; Hong, 1997; Zhang and Fan, 2004; Kim et al., 2003; and Caminal, 2004).

It is a common belief that growth and equity are mutually exclusive, but this is not true of the discrepancy between regional disparity and economic growth. Therefore, since the 1950s, many researchers have investigated this relationship. This section focuses on three specific questions that help clarify the relationship between health disparity and the built environment. First, what is the relationship between regional disparity and economic development? Second, what kinds of policies have been implemented for reducing regional disparity? Finally, what have been used as indicators and measurements of regional disparity?

### *(a) Regional Disparity and Economic Development*

According to the theory of agglomeration economies, economic development is achieved by the clustering of labor, money, and information in one place (Evans, 1972). Conversely, one side effect of an agglomeration economy is an agglomeration diseconomy. This means that the growth of a city results in problems such as crime, traffic congestion, and pollution; all of which eventually become obstacles to economic development. This clustering of population, capital, and technology naturally brings regional disparity.

The pattern of regional disparity as national economic development increases is one of the major research topics in urban economics and regional science. It has been widely discussed and well documented by regional scientists and urban planners. Kuznets (1955) developed the 'inverted-U curve hypothesis,' which states that inequalities first rise as economic development increases, but later begin to fall once a certain point is reached. While Kuznets applied the hypothesis to personal level inequality, Williamson's (1965) directing and testing of the concept toward regional inequality concluded that the hypothesis is valid.

Amos (1988) reported that regional inequality goes up again at the end of inverted-U curve (Figure 2.2). He explained the pattern of this augmented inverted-U curve using annual data from all 50 states from 1969 to 1983. Following the studies by Williamson and Amos, many researchers have demonstrated both the inverted-U and the augmented inverted-U patterns with data from all over the world (McGillivray and Matthew, 1991; Barro and Sala-i-Martin, 1992; Fan and Casetti, 1994; Levernier et al., 1995; Chen and Fleisher, 1996; Sala-i-Martin, 1996; Kim and Kim, 2002; Kim et al., 2003; and Kim and Kim, 2005).

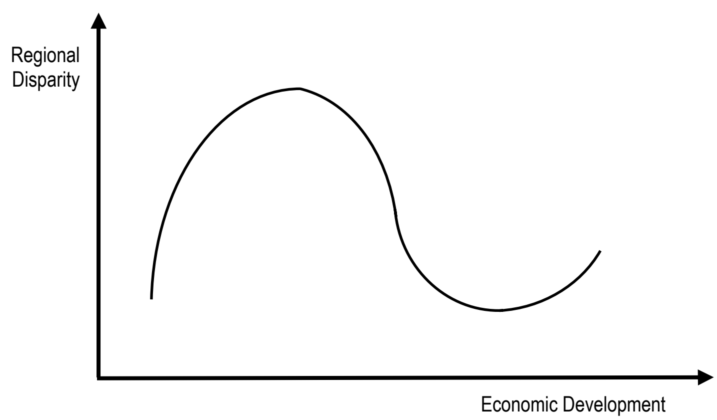


Figure 2.2. Pattern between Economic Development and Regional Disparity (Inverted-U and Augmented Inverted-U Patterns) (Adapted from Amos, 1988)

***(b) Policy Implications of Regional Disparity***

Regional disparity beings hundreds of physical and social problems to human life; e.g. traffic congestion, caused by spatial discrepancies between the home and the work place, wastes time, money, and energy. Moreover, inequality heightens a sense of relative poverty.

Levernier, Rickman, and Patridge (1995) examined U.S. state income inequality in general over the period of 1960 to 1990. A topography of state income inequality demonstrated that states with high-income inequality in 1959 were concentrated in the south. By 1989, this inequality had begun to spread out more evenly. They used the Gini coefficient as a measure of inequality and it was the dependent variable in their multiple regression model. The results showed that greater rates of high school graduation, labor-force participation, goods-producing employment share, and transfer payment were correlated with reduced income inequality.

Zhang and Fen (2004) analyzed the effects of public investment on regional inequality in rural China. Their data included figures from 25 provinces between 1978 and 1995. They applied the Cobb-Douglas production function[1] with conventional inputs (labor, capital, and land) and public investments (roads, education, electricity, telephones, irrigation, and agricultural research and development capital). The results showed that educational and agricultural research and development (R&D) in the western region

[1] It is functional form of production function in economics introduced by Charles W. Cobb and Paul H. Douglas in 1928. It is widely used modeling form to relationship between inputs and an output. Its basic function is $Y = AL^{\alpha}K^{\beta}M^{\gamma}$ (Y=output; L=labor input; K=capital input; M=material and supply).

(most poor are concentrated in that area) were the most effective in decreasing regional inequality.

In 1879, Henry George had proposed the, “abolition of all taxation save that upon land values,” now known as the single tax. In a study that focused on the impact of alternative tax systems on regional inequality in Korea (Kim and Kim 2005), the concept of the single tax was proposed as one possible solution to alleviate income inequalities. Fifteen proposed policies were simulated with several combinations of decreasing rates in production tax and increasing rates in land tax. The most effective scenario was a policy that involved a small increase in the land tax and a moderate cut in the production tax.

***(c) Indicator and Measurement for Regional Disparity***

Indicators and measurements of regional disparity are shown in Table 2.2. Per capita income and GDP are used as indicators while convergence, CV, $CV^2$, Theil, and the Gini coefficient are employed as measurements for inequality.

The Gini coefficient has been routinely used for estimating levels of regional disparity (e.g., Al-Samarrie and Miller, 1967; Amos, 1983, 1986, Kim and Kim, 2002; Levernier et al., 1995; Kim et al., 2003, and Kim and Kim, 2005). Both per capita income and GDP have also been used as indicators of regional disparity (Table 2.2). Al-Samarrie and Miller (1967) began to use the Gini coefficient to measure personal income disparity in the US and the US Census started to consider the Gini coefficient as an index of income concentration for each state in 1970. From that day to this, the Gini coefficient has employed to gauge the degrees of regional and income inequalities in many countries as well as in the US.

Table 2.2. Literature Sources, Indicators, and Measures of Regional Disparity

| Indicator | Measurement | Source |
|---|---|---|
| Per capita income | Gini coefficient<br>B-convergence<br>σ-convergence<br>Variance of Logs<br>Atkinson<br>Theil<br>CV<br>$CV^2$<br>WCV | Williamson (1965)<br>Al-Samarrie and Miller (1967)<br>Amos (1983, 1986, 1988)<br>Barro and Sala-i-Martin (1992)<br>Sala-i-Martin (1996)<br>Benjamin, Brandt, and Giles (2005)<br>Dowrick and Akmal (2005)<br>Materia et al. (2005)<br>Voitchovsky (2005) |
| GDP | Gini coefficient<br>CV<br>WCV<br>Log variance | Levernier, Rickman and Patridge (1995)<br>Kim and Kim (2002)<br>Kim et al. (2003)<br>Zhang and Fan (2004) |
| Per capita GDP | Gini coefficient | World Bank (2001) |
| Local government financial index, per capita GRDP | Gini coefficient<br>CV | Kim and Kim (2005) |

GDP: Gross Domestic Product
GRDP: Gross Regional Domestic Product
CV: Coefficient of Variance
$CV^2$: Squared CV
WCV: Weighted CV

The extensive research on regional disparity can be useful for improving the understanding of health inequality in three areas: (1) measurement methods, (2) policy implication, and (3) spatial conceptualization. In addition to regional disparity, health disparity also uses detailed and precise statistical measurement methods. Thus, specific tools for measurement as well as the general concepts, trends, and policy implications of disparity research are useful for health disparity research.

### 2.4.2.2. Environment and Obesity

There is a growing agreement among experts that the environment, in addition to genetics, is a major contributing force behind the current obesity epidemic. Poston and Foreyt's study (1999) on the relationship between obesity and the environment suggested that the cause of obesity was not found in genetics, but in the environment. Hill et al. (2003) also agreed with this study, but they insisted that biology also contributed to individual differences in weight and height. Nevertheless, increasing evidence suggests that the rapid weight gain that has occurred over the past three decades is clearly, to a great extent, due to the changing environment. This leads to a question: what kind of social and built environmental factors contribute to the obesity epidemic?

Several articles have proposed a number of environmental factors. Based on Poston and Foreyt's (1999) classifications, there are four types of environmentally relevant determinants of obesity: (1) caloric consumption (dietary patterns), (2) sedentary life style (physical inactivity), (3) socio-economic status (SES), and (4) place of residence. These factors are all interrelated and have a considerable correlation with the pattern of obesity.

Obesity-prone environments essentially encourage the consumption of food, especially unhealthy, energy-dense food and/or discourage physical activity (Hill and Peters, 1998). This environmentally induced change in the energy balance results in an increased tendency to become overweight or obese (Chisholm et al., 1998; Price and

Gottesman, 1991; Weinsier et al., 1998). Physical inactivity and diet pattern are two major behavioral factors directly linked to obesity.

Numerous recent studies based on the social components of obesity focused on socio-economic status (SES) as a determinant. Generally, these findings showed a negative correlation between obesity and SES (Jeffery et al., 1989; Reijneveld, 1998; Sundquist and Johansson, 1998; Sundquist et al., 1999). As SES declined, the risk of obesity increased. On the other hand, Popkin et al. (1995) connected obesity with economic development at the national level. They concluded that whether it had a positive or negative correlation, the relationship between obesity and SES changes depending on the degree of economic development. In developing countries, there was a positive correlation between obesity and SES, while in developed countries, obesity was negatively correlated to SES. In other words, the obesity-SES relationship is dependent on economic development at the individual and national levels.

Poston and Foreyt (1999) found that residents living in impoverished neighborhoods had a higher BMI, larger waist circumference, and higher waist-to-hip ratio. In addition, more impoverished residents perceived their neighborhood as not safe in comparison to their counterparts. Ewing et al. (2003) examined the relationship among urban sprawl, health status, and health related behaviors in 448 U.S. counties and 83 metropolitan areas with the BRFSS data. Their model used the sprawl index as the dependent variable with levels of physical activity, obesity, hypertension, diabetes, and coronary heart disease as independent variables. The results showed that the sprawl index had a significant association with minutes walked, obesity, and hypertension.

Although there was little difference in the actual sprawl index values between county and metropolitan areas, they concluded that places of residence had an impact on obesity based on statistically significant results.

Based on the above findings, Kim (2004) studied the effects of SES and environmental factors on obesity levels. Through a multiple regression model using the Walkable and Bikable Communities (WBC)[2] survey data, the SES and environmental factors were found to have significant effects on the occurrence of obesity. It was concluded that age and frequency of 'eating-out' have a positive relationship with BMI. Education, income, walking, transit use, and physical activity are negatively correlated with BMI. These results are consistent with findings from several previous studies reviewed at the beginning of this chapter.

Frank, Andresen, and Schmid (2004) identified the correlates of urban form and travel patterns with obesity using the logistic regression analysis. Urban form variables included land use mix, connectivity, and residential density while travel pattern variables were walking distance and time spent in a car. Findings from this model showed that land use mix, time spent in a car, and walking distance were significantly correlated with obesity. After controlling for age, income, and education, they used the linear Pearson correlation to test the relationship between BMI, walking distance, and car time and urban form for four ethnicity and gender classifications (black, white, male, female). The

[2] The WBC project was funded by CDC (PI: Dr. Anne Vernez Moudon) and conducted by Urban Form Lab and Health Promotion Research Center at the University of Washington. The data is based on a 30 minute telephone survey administered to 608 able-bodied respondents randomly selected in an 80 square mile area of urban and suburban areas in the Puget Sound (Seattle) region.

BMI, walked distance, and car time were associated with each urban form variables for white cohorts only.

### 2.4.2.3. Environment and Physical Activity

One of the main determinants of obesity is physical inactivity. Advances in technology and motorized transportation have reduced the need for physical activity in daily life. The appeal of television, electronic games, and computers has increased the time spent in sedentary pursuits among children and adults (Hill and Peters, 1998; Poston and Foreyt, 1999). A low level of physical activity is associated with low daily energy expenditure, which in turn contributes to obesity unless food intake is reduced accordingly.

Lee and Moudon (2004) reviewed the public health literature dealing with the association between the built environment and physical activity. They found that the level of physical activity is correlated with access to recreational facilities, local destinations, neighborhood safety, as well as the aesthetic quality of the environment. The study concluded with the recommendation to create paths for walking, jogging, and biking and to locate routine destinations close to residential areas to help promote active living.

Powell, Martin, and Chowdhury (2003) studied the role of the built environment on the level of physical activity by using the Georgia Behavioral Risk Factor Surveillance System (BRFSS). They categorized walking places based on time and mode of travel. Results revealed that neighborhood streets or sidewalks (32%) were the most commonly reported places used for physical activity, with public parks (26.8%) coming second. These locations were most frequently reported as being safe and convenient places for walking. It was also shown that proximity is another important factor in determining a convenient and safe place to walk. The most commonly mentioned locations were extremely close to the respondent's house. Overall, proximity, safety, and convenience factors were all important elements that encourage people to walk.

Leslie et al. (2007) identified the relationship between perceived and objective measures of the built environment and further their correlates with physical activity in Forsyth County, NC and Jackson County, MS. Perceived built environment data was derived from a telephone survey (N=1,270) and found that neighborhood perceptions of high-speed cars, heavy traffic, and a lack of crosswalks or sidewalks had negative relationships with physical activity. On the other hand, existence of neighborhood destinations was positively correlated with physical activity including walking. GIS software derived objective built environmental factors including speed, volume, and street connectivity. Although this study shows little agreement between the perceived and objective built environment as calculated by kappa coefficients in either area, there is a clear finding that the built environment is a significant correlate of physical activity.

#### 2.4.2.4. Environment and Diet Pattern

Hill and Peters (1998) mentioned that food availability, portion size, and a high fat diet promoted overeating. The film, Super Size Me, also indicated that a variety of highly palatable, inexpensive foods are now available everywhere and the “super sizing” of menu items is very common. In numerous studies, the total energy intake is higher when subjects consume food relatively high in fat than when they consume food that is relatively low in fat. Recognizing the importance of energy density is a step forward in comprehending how food composition affects total energy intake, but reductions in dietary fat may still be the most effective means of decreasing the likelihood of excessive energy consumption.

By focusing on the environment, especially the built environment, Story et al. (2002) analyzed individual and environmental effects on adolescent eating behaviors by using an ecological model. He considered schools, fast food restaurants, vending machines, convenience stores, and worksites (for part-time jobs) as important built environments which had a significant impact on adolescents’ food choices and dietary patterns. Foods that were sold by these places normally contain ingredients that were high in fat and sugar. Story et al. also proposed strategies to reduce adolescent obesity and encourage healthier food choices at the interpersonal and community levels. He recommended family and peer support for encouraging healthful eating and discouraging high fat and high sugar foods as well as alcohol and tobacco uses at the interpersonal level. Community level of intervention was also suggested to reduce environmental barriers to healthy food choices and to control unhealthy foods such as soft drinks and high sugar/high fat foods.

There are some empirical studies on how much and to what extent environmental factors influence dietary choices. Kipke et al. (2007) concluded that the food environment around schools was one of the primary factors influencing childhood obesity and examined how the food environment factor, in addition to physical activity-related destinations, correlated with obesity in the community with higher rate of childhood obesity. The study site was East Los Angeles, CA which has a high prevalence of childhood obesity. The finding clearly described that there was abundant availability in fast food restaurants (49% was fast food restaurant out of 190 food outlets) and limited access to healthy food destinations (only 18% out of 62 grocery stores provided vegetables and fruits). Cheadle et al. (1991) found that fruit and vegetable intake was positively associated with the number of supermarkets in African American neighborhoods. When each additional supermarket came to the neighborhood, African and white Americans' fruit and vegetable intake increased by 32% and 11%, respectively (Morland et al., 2002). Morland and colleagues also found that wealthy neighborhoods had four times more supermarkets than low-income neighborhoods. Similarly, some researchers reported that wealthier zip code areas had more supermarkets than poor zip code areas (Alwitt and Donley, 1997; Cotterill and Franklin, 1995; Weinberg, 2000). Zenk et al. (2005) noted that the average distance from the home to the nearest supermarket in the poorest neighborhoods was 1.1 miles further than the distance in the richest neighborhoods. Block et al. (2004) investigated how the density of fast-food restaurants related to the household income and ethnicity in New Orleans, Louisiana. They found that the high density of fast-food restaurants was positively correlated with low household income and a higher percentage of African American residents.

Although food cost is an important factor, the environmental factor is another key in a low-income population's ability to buy healthy food. As described above, there is a clear connection between environment and dietary patterns. Since poor diet habits are closely linked with obesity, cardiovascular disease, cancer, and even mortality, it is necessary to promote healthy diet habits.

### 2.5. Conclusion

This review of literature attempts to understand the relationship between health disparity and the built environment in two respects.

First, it considers the inter-relationship between regional disparity and health disparity. Even though these two topics remain largely separate thus far, there are a few recent studies that address both issues together. This review showed that measurement methodologies from regional disparity literature can help advance and expand health disparity research.

Second, this review confirms that the built environment is a significant factor contributing to the increased levels of obesity, physical inactivity, and overeating or unhealthy dietary habits. These behavioral outcomes, obesity, physical activity, and diet, are interconnected and the literature shows that the built environment plays an important role in affecting the levels of obesity and increasing trends toward more active life styles.

Based on this proposed conceptual framework based on ecological theory, general systems theory, and the behavioral model of environment (BME) as well as the review of relevant empirical studies from the fields of urban design and planning, public health and epidemiology, and regional science, the research hypotheses and the methods to test these hypotheses for this dissertation are refined.

# CHAPTER III

# METHODS

## 3.1. Research Design, Aims, and Hypotheses

The three phases, as described in Table 3.1, are designed to address the previously mentioned specific aims of this study. The phases move from exploratory to explanatory, and aggregated to disaggregated analyses. Accordingly, the units of analysis range from the state level to individuals. The outcome of studies for the three aims will be translated into policy recommendations to reduce geographic inequalities in health while reducing obesity and improving health status.

Table 3.1. Research Design and Components

Resolution Coarse ⟷ Fine

| | Aim One | Aim Two | Aim Three |
|---|---|---|---|
| Aim | (1)To examine aggregated longitudinal trends in health disparity<br>(2) To examine regional differences of health disparity among the four census regions<br>(3)To identify aggregated socio-economic correlates of health disparity | (1)To examine individual health disparity and its spatial autocorrelation<br>(2)To test the significance of geographic concentrations of high health disparities (hotspot) | To examine the built environmental correlates of health status, obesity, and health disparity |
| Disparity Measure | Gini coefficient | Gini Coefficient | Gini coefficient |
| Analytical Methods | ANOVA<br>Pearson Correlation | ANOVA<br>Moran's I<br>LISA Map | Pearson Correlation<br>Multiple Regression Model<br>Spatial Regression Model |
| Coverage | The US | Urbanized part of King County, WA | Urbanized part of King County, WA |
| Spatial Unit of Analysis | State | Individual | Zip code, Individual |
| Data Source | BRFSS (1995-2004)<br>Census (2000) | WBC data (2003) | WBC data (2003) |

Table 3.1. (Continued)

| | Aim One | Aim Two | Aim Three |
|---|---|---|---|
| Outcome | Maps showing the historic trend of health disparity by State (1995 - 2004)<br>Statistical results showing the directions (positive/negative) and magnitude of correlation between socio-economic factors and health disparity | Maps showing the health disparity at the individual level<br>Maps showing the health disparity of individual compared to his/her neighbors<br>Maps showing the local spatial autocorrelation<br>Statistical results showing the directions (positive/negative) of built environmental factors on hot and cold spots | Maps showing the health disparity at the zip code level<br>Statistical results showing the directions (positive/negative) and magnitude of correlation of built environmental factors on health disparity |

### 3.1.1. Aim One: Aggregated Longitudinal and Regional Trends in Health Disparity

Self-reported health status and obesity (measured in Body Mass Index, BMI) are used as indicators of health to measure disparity. Perceived health status is selected as a global indicator of health. It has been popularly used in previous literatures as a predictor of mortality (Idler and Benyamini, 1997). This indicator has been used for cross-country comparison of health disparity levels because it is easy to capture and has only marginal variance among surveys (Van Doorslaer et al, 1997, 2000; Van Doorslaer and Koolman, 2004). Advantage for a perceived health status is that it is easy to understand. It does not rely on a medical conceptualization and employs individuals' evaluations of their own health (Van Doorslaer et al, 1997). Obesity is selected as a more specific and objective indicator of health risk. The literature shows that obesity is an indicator of many common chronic health conditions and risks. Further, it has shown continued growth in prevalence in the US. Therefore, this dissertation uses perceived health status and obesity as subjective and objective indicators of health conditions, respectively. The Gini coefficient is used as the measurement method for estimating disparity in this research because it is commonly-used, valid, effective, and easy to compare and understand.

Historic trends between 1995 and 2004 are displayed with GIS maps and the longitudinal trend graphs. For the relationship between socio-economic factors and disparity, the Pearson correlation coefficient (R) is used.

### 3.1.2. Aim Two: Disaggregated Analysis of Geographic Concentrations of Health Disparity

To examine the spatial patterns of areas with concentrations of high levels of health disparity, this study employs a Moran's I and a Local Index of Spatial Association (LISA) map identifying global and local spatial autocorrelations. It is extend to identify built environmental correlates of high levels of health disparity (hot spots). The results highlight modifiable environmental variables that may contribute to reducing health disparity. A hypothesis given in this study is tested as follow:

> <u>*Hypothesis One*</u>*: Areas with supportive built environmental conditions are less likely to be associated with hot spots (areas with greater variances in health disparity among neighboring individuals).*

In this study, a "supportive built environment" is defined by a set of variables identified from previous literature, that are shown to increase active living, healthy diet, and positive health outcomes, and to reduce health disparities.

### 3.1.3. Aim Three: Disaggregated and Multivariate Analysis of the Built Environmental Correlates of Health Status, Obesity, and Health Disparity

The third aim of this study examines the relationships between the built environment and health status, obesity, and health disparity at the zip code and individual levels. The zip code level analysis implements the bivariate correlation between them. The individual level analysis identifies the built environmental correlates of health status, obesity, and health disparity using a multiple regression model based on the bivariate correlation results at the zip code level.

This study considers two major forces (built environments and personal factors) potentially related to health disparity as drawn from a review of previous studies. Specifically, the built environment is identified as the key independent variable for this research. Figure 3.1 describes the theoretical framework used to select variables for multiple regression analyses estimating the levels of health disparity (indicators are health status and obesity). More supportive built environments will enhance health status, reduce obesity, and alleviate health disparity.

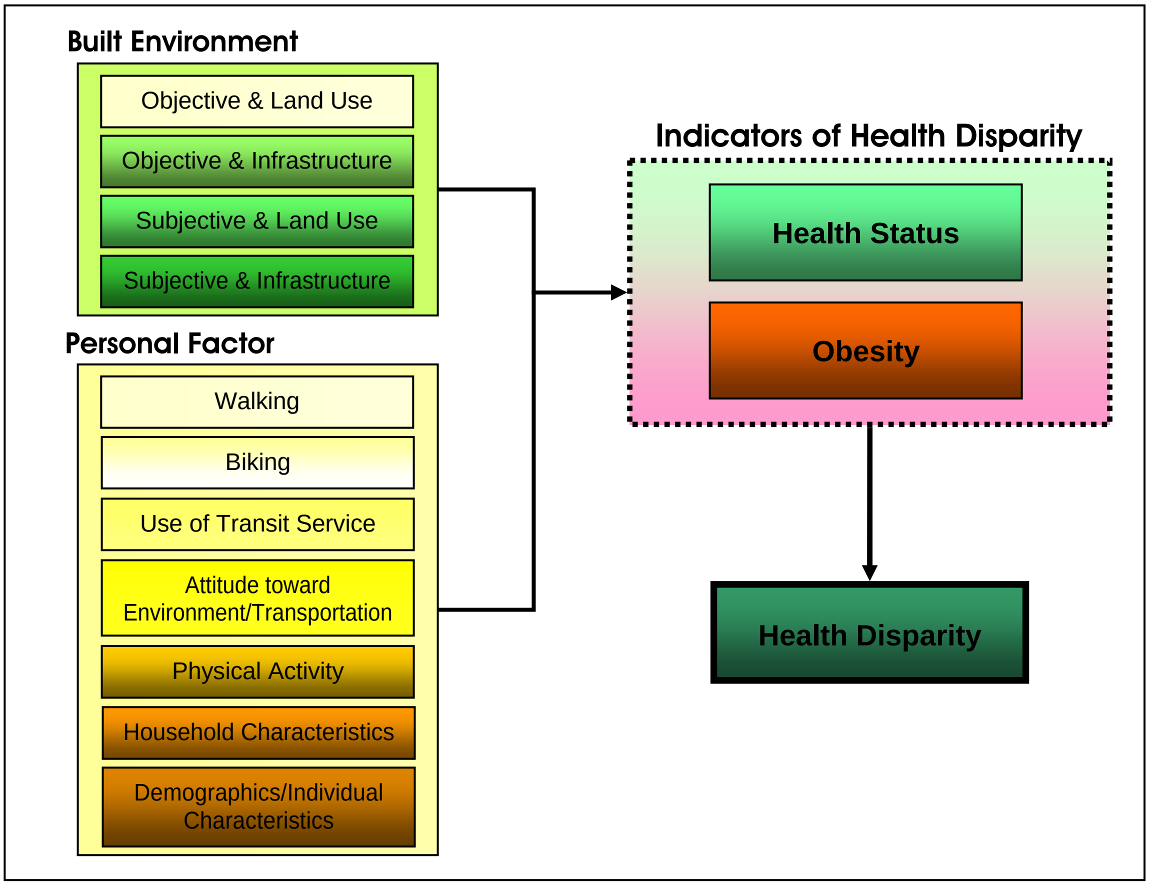


Figure 3.1. Effects of Built Environment on Health Status, Obesity, and Health Disparity

Based on the literature review, three hypotheses will be tested:

*<u>Hypothesis Two</u>: Areas with more supportive built environments have a lower health disparity than areas with less supportive built environments.*

*<u>Hypothesis Three</u>: Areas with more supportive built environments have a higher health status than areas with less supportive built environments.*

*<u>Hypothesis Four:</u> Areas with more supportive built environments have a lower obesity than areas with less supportive built environments.*

The independent variables are the built environmental variables, and the control variables are personal factors. Multivariate regression models are used to identify significant correlates in health disparity.

## 3.2. Study Area and Data Collection Methods

### 3.2.1. Aim One

For this initial exploratory step, the Behavioral Risk Factor Surveillance System (BRFSS), a national longitudinal health data set collected by the Centers for Disease Control and Prevention (CDC), are used to provide the individual-level health and behavioral data. Three questions from the BRFSS, perceived general health status and BMI (height and weight questions), are used to develop the two indicators of health disparity. The analyses are done at the state level from 1995 to 2004, and the trend results are presented in GIS maps following the format that the CDC used to illustrate the obesity trend. The US Census Bureau provided the state-level data, including population density, age, the percentage of the population below the poverty level, income, education, ethnicity, car ownership, and the percentage of the population using public transportation. The Gini coefficient is selected as the preferred method for measuring disparity because of its efficiency, effectiveness, and ease of interpretation. Its values range from zero (perfect equality) to one (perfect inequality). For correlation analyses, the Pearson correlation coefficient (R) is used.

### 3.2.2. Aims Two and Three

Compared to the first aim covering the entire US to identify the overall magnitude and the longitudinal trends of health disparity, the second and third aims focus on the City of Seattle and its surrounding areas. This specific study area is selected because of available survey and GIS data from a previous study and diverse environmental settings.

This study uses the 608-repondent telephone survey and the Geographic Information System (GIS) data generated from the WBC project (Walkable and Bikable Communities project, PI: Dr. Anne Vernez Moudon) (2001 – 2004). It was funded by the Centers for Disease and Control and Prevention (CDC) and carried out by the Health Promotion Research Center at the University of Washington. The study area (Figure 3.2) covers 80 square miles of urban Seattle and its surrounding suburban areas in the Puget Sound region in Washington (Moudon et al, 2007). Telephone survey captures demographic and household characteristics, recreational and travel behavior, neighborhood perception, and attitude toward environment. The objective measures of physical environments come from parcel and network GIS databases, and are captured using a custom-made GIS extension called WBC Analyst (also developed as part of the WBC project).

The WBC project employed a spatial sampling instead of the traditional sampling strategies to ensure appropriate distribution and variations in the environmental variables (Lee et al., 2006). This sampling process is composed of: (1) defining the conceptual population, (2) defining the spatial extent of the population and establishing a sampling frame, (3) examining the spatial sample frame, and (4) determining the sample design and size, and drawing samples. Each step has the following content. A notable point is that GIS functions on parcel-level GIS data delineate the spatial sampling frame according to the defined criteria. This study selects areas with a minimum level of support for walking and biking conducted by residential density (10 or more dwellings per acre) and proximity to neighborhood retail use (240 meters or less). This sampling approach maximizes the validity and economizes the cost of the study. More detailed information of this sampling strategy, such as the theoretical and methodological foundation and application process, is found in Lee et al. (2006).

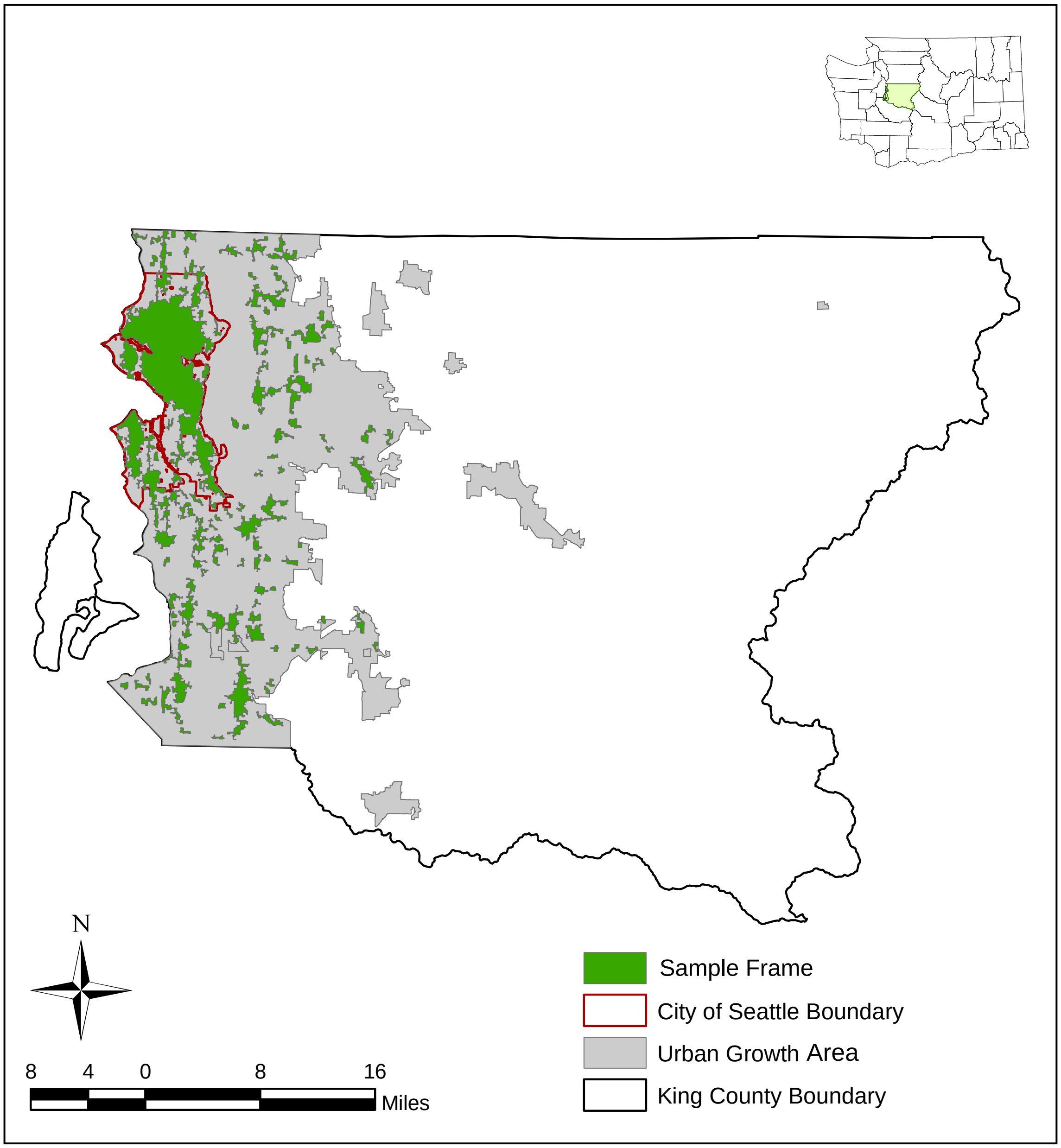


Figure 3.2. Study Area for Second and Third Aims (Adapted from Lee et al., 2006)

## 3.3. Measurement and Variables

### 3.3.1. Aim One

#### 3.3.1.1. Health Status Measure

Health status comes from the survey question about general health. The question is, "Would you say that in general your health is ___?" Its response items are a 5-point Likert scale including: excellent, very good, good, fair, and poor.

#### 3.3.1.2. Obesity Measure

Obesity is measured by the Body Mass Index (BMI) and the individual's BMI is calculated by personal weight and height. The exact survey question of reported weight in pounds is, "About how much do you weight without shoes?" And the question of reported height in feet and inches is, "About how tall are you without shoes?" BMI is calculated by the following formula:

$$BMI = \frac{weight(lb)}{[height(in)]^2} \times 703$$

#### 3.3.1.3. Health Disparity Measures

To analyze health disparity, this study uses the Gini coefficient, which is the measure of aggregated inequality and varies from zero (perfect equality) to one (perfect inequality). It is derived from the Lorenz curve, which plots the cumulative proportion of the population on the x-axis and the cumulative proportion of the variable of interest on the y-axis (Figure 3.3). In order to measure health disparity, the x-axis tracks the cumulative proportion of the population by health level and the y-axis the cumulative proportion of the health variable (e.g. perceived health status and BMI). The Lorenz curve and Gini coefficient equations are presented below.

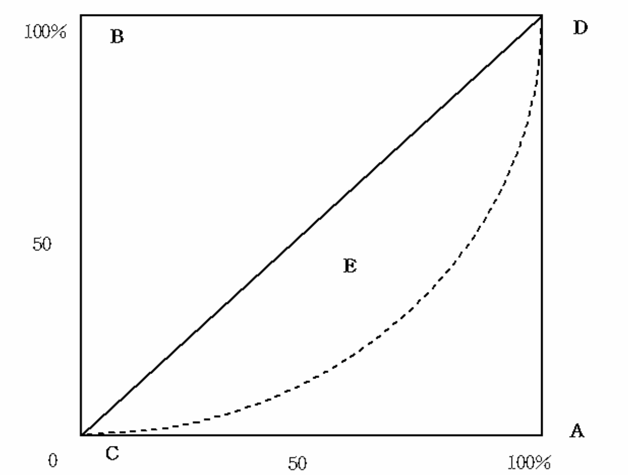


Figure 3.3. Lorenz Curve

$$\text{Gini coefficient} = \frac{E}{\Delta CAD}$$

In this simulation, the Gini coefficient formula is presented as follows.

$$G_t = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|y_i - y_j\right|}{2n^2\bar{y}}$$

$y_i$ : Value of the health indicator (e.g. perceived health status and BMI) in group i
$y_j$ : Value of the health indicator in group j
$\bar{y}$ : Average of the health indicator
$n$ : Number of groups (e.g. total numbers of states)

Aims two and three also use the Gini coefficient as the health disparity measure at the zip code and individual levels.

### 3.3.1.4. Socioeconomic Variables

Testing the influence of the socioeconomic factors at the state-level involves age, education, household income, the percentage of the population below the poverty level, car ownership, population density, the percentage of the population using public transportation, and ethnicity. These variables are selected based on the previous literature. The descriptive statistics of these variables are described in Table 3.2.

Table 3.2. Descriptive Statistics of Socioeconomic Variables

| Variable | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| Gini coefficient of health status | .14486 | .22126 | .17174 | .01621 |
| Gini coefficient of BMI | .10251 | .11921 | .11051 | .00436 |
| Median age | 27.10 | 38.90 | 35.52 | 1.89 |
| % of high school + | 72.90 | 88.30 | 81.88 | 4.36 |
| Median income per HH ($) | 29,696.00 | 55,146.00 | 41,346.75 | 6286.24 |
| % of pop below poverty | 6.50 | 20.20 | 12.10 | 3.30 |
| % of no vehicle pop | 4.60 | 36.90 | 9.24 | 5.37 |
| Pop density | 1.10 | 9316.40 | 361.00 | 1302.84 |
| % of pop using public trans | .40 | 33.20 | 3.51 | 5.72 |
| % of white pop | 24.30 | 96.90 | 78.52 | 14.53 |

### 3.3.2. Aim Two

All variables, including health status, obesity measured by BMI, two types of health disparities (e.g. health status disparity and obesity disparity), and the built environmental and personal variables for hot spot analysis are the same with the variable list of the individual regression model in the third aim of the study. Specific variable lists and their descriptive statistics will be presented later.

### 3.3.3. Aim Three

Variables used for bivariate correlation analysis at the zip code level are used in the multiple regression model at the individual level. Even though there is no classification of variables such as dependent and independent factors in the correlation test at the zip code level, a variables list including coding and descriptive statistics is shown in the description of the individual level study together.

#### 3.3.3.1. Dependent Variables

The dependent variables are perceived health status, obesity, and the Gini coefficients in both health status and BMI. Health status (self-reported health status recorded on a 5-point Likert scale, ranging from poor to excellent) comes directly from the WBC survey; obesity measured by BMI is a calculated value from two WBC survey questions on height and weight. The perceived health status is transformed into a dichotomous scale lumping the 5-point Likert scale into two groups (e.g. zero, good; one, excellent).

Table 3.3. Descriptive Statistics of Dependent Variable

| Variable | Measurements | Coding and Descriptive Statistics | |
|---|---|---|---|
| | | Zip Code Level (N=25) | Individual Level (N=503) |
| Health Status Disparity | **Ratio:** Gini coefficient in health status | Mean=.129, SD=.027 | Mean=0.125, SD=0.014 |
| Obesity Disparity | **Ratio:** Gini coefficient in BMI | Mean=.087, SD=.019 | Mean=0.087, SD=0.016 |
| Health Status | **Ratio/Nominal:** Perceived health status | Mean=2.860, SD=.451 | 0=good: 171, 1=excellent: 332 |
| Obesity | **Ratio:** Body mass index | Mean=2.242, SD=1.177 | Mean=25.284, SD=4.435 |

All four dependent variables shown in Table 3.3 are used as predictors to measure the others. For example, the perceived health status and the Gini coefficients in health status and BMI are used as independent variables for measuring obesity. Thus, all four dependent variables also assume the roles of independent variables in a multivariate regression model measuring the other dependent variables.

### 3.3.3.2. Independent Variables

Variables are selected based on a literature review and the conceptual framework of this study. A large pool of variables is considered due to the lack of sufficient theory or empirical evidence available for guiding the selection of specific disaggregated measures and their measurement types. As explained in above section, four dependent variables, including health status disparity, obesity disparity, health status, and BMI, are used as independent variables. All variable coding and descriptive statistics are the same except for perceived health status at the individual level. As an independent variable, individual health status is a categorical value (e.g. 1-poor through 5-excellent) while it is dichotomous as a dependent variable (e.g. 0-good, 1-excellent).

Built environmental factors, the independent variables, are classified into objective and subjective variables, and they are further divided into land use and infrastructure variables. The objectively measured land use variables include spatial characteristics in terms of household density, distance to downtown, land use mix, and the number of each destination land use type. These objective data comes from the GIS measure.

Table 3.4. Descriptive Statistics of Independent Variables: Objectively Measured Land Use Built Environmental Variables

| Variable | Measurements | | Coding and Descriptive Statistics | |
|---|---|---|---|---|
| | | | Zip Code Level (N=25) | Individual Level (N=503) |
| Household Density | Ratio: Dwelling units per acre (logged) | | Mean=3.765, SD=.292 | Mean=2.944, SD=1.079 |
| Distance to Downtown | Ratio: Distance to Seattle downtown (ft) | | Mean=38343.117, SD=29896.536 | Mean=26712.911, SD=17612.226 |
| Land Use Mix | Ratio: Land use mix*:0(single use) ~1(perfect mixing) | | Mean=0.460, SD=0.085 | Mean=0.460, SD=0.102 |
| Destination | Ratio: Number of each destination within a 1km network buffer | Bank | Mean=8.400, SD=4.787 | 10=0, 11=1, 12=2+ (Mean=11.050, SD=1.304) |
| | | Bar | Mean=2.640, SD=3.108 | 10=0, 11=1-2, 12=3-4, 13=5-6, 14=7-8, 15=9+ (Mean=10.600, SD=.792) |
| | | Big box retail | Mean=.640, SD=.757 | 10=no: 463, 11= have one or more:40 |
| | | Church | Mean=28.200, SD=15.832 | 10=0, 11=1-4, 12=5-8, 13=9-12, 14=13-16, 15=17-20, 16=21-24, 17=24+ (Mean=12.093, SD=1.555) |
| | | Neighborhood/Community shopping center | Mean=6.160, SD=7.925 | 10=no: 399, 11= have one or more:104 |
| | | Convenience store | Mean=10.600, SD=9.256 | 10=0, 11=1, 12=2, 13=3, 14=4+ (Mean=11.533, SD=1.291) |
| | | Day care center | Mean=3.280, SD=3.143 | 10=no: 356, 11= have one or more:147 |
| | | Fast food restaurant | Mean=7.720, SD=7.015 | 10=0, 11=1, 12=2, 13=3, 14=4+ (Mean=11.091, SD=1.334) |
| | | Fitness center | Mean=1.320, SD=1.464 | 10=no: 431, 11= have one or more:72 |
| | | Grocery store | Mean=8.120, SD=4.034 | 10=0, 11=1, 12=2, 13=3, 14=4, 15=5, 16=6+ (Mean=12.237, SD=1.890) |
| | | Hospital | Mean=19.520, SD=14.169 | 10=0, 11=1-2, 12=3-4, 13=5-6, 14=7-8, 15=9+ (Mean=12.054, SD=1.695) |

Table 3.4. (Continued)

| Variable | Measurements | | Coding and Descriptive Statistics: Zip Code Level (N=25) | Coding and Descriptive Statistics: Individual Level (N=503) |
|---|---|---|---|---|
| Destination | Ratio: Number of each destination within a 1km network buffer | Library | Mean=1.280, SD=.843 | 10=no: 368, 11= have one or more:135 |
| | | Mixed use | Mean=27.640, SD=28.411 | 10=0, 11=1-15, 12=16-30, 13=31-45, 14=45+ (Mean=11.209, SD=.767) |
| | | Museum | Mean=1.480, SD=1.388 | 10=no: 374, 11= have one or more:129 |
| | | Office | Mean=103.480, SD=67.966 | 10=0, 11=1-10, 12=11-20, 13=21-30, 14=31+ (Mean=12.133, SD=1.259) |
| | | Post office | Mean=1.040, SD=.841 | 10=no: 373, 11= have one or more:130 |
| | | Regional shopping center | Mean=.680, SD=2.795 | 10=no: 493, 11= have one or more:10 |
| | | Restaurant | Mean=29.720, SD=16.064 | 10=0, 11=1-5, 12=6-10, 13=11-15, 14=16-20, 15=21+ (Mean=11.915, SD=1.436) |
| | | Retail store | Mean=108.000, SD=56.423 | 10=0, 11=1-15, 12=16-30, 13=30-45, 14=46-60, 15=61+ (Mean=12.312, SD=1.467) |
| | | School | Mean=23.000, SD=9.950 | 10=0, 11=1-2, 12=3-4, 13=5-6, 14=7-8, 15=9+ (Mean=12.342, SD=1.609) |
| | | Sport facility | Mean=2.880, SD=1.856 | 10=no: 313, 11= have one or more:190 |
| | | Theater | Mean=1.920, SD=1.824 | 10=no: 334, 11= have one or more:169 |
| | | Park | Mean=14.040, SD=13.328 | 10=0, 11=1-2, 12=3-4, 13=5-6, 14=7-8, 15=9+ (Mean=1.624, SD=1.540) |
| | | Trail | Mean=12880.607, SD=21228.426 | 10=no: 356, 11= have one or more:147 |
| | Ratio: Number of each neighborhood center (NC) within a 1km network buffer | NC used for grocery stores and retail stores | Mean=4.480, SD=2.275 | Mean=1.594, SD=1.322 |
| | | NC used for grocery stores, restaurants, and retail stores | Mean=3.920, SD=1.977 | Mean=1.439, SD=1.179 |
| | | NC used for grocery store and restaurants | Mean=2.720, SD=1.621 | Mean=.905, SD=1.111 |
| | | NC used for convenience stores, restaurants, and grocery stores | Mean=2.080, SD=1.412 | Mean=.501, SD=.592 |
| | | NC used for offices and mixed uses | Mean=6.520, SD=4.114 | Mean2.716=, SD=2.075 |
| | | NC used for sports facilities and schools | Mean=.880, SD=.833 | Mean=.421, SD=.657 |
| | | NC used for churches and schools | Mean=5.600, SD=2.944 | Mean=1.742, SD=1.629 |
| | | Number of NC used for offices | Mean=9.880, SD=6.710 | Mean=2.509, SD=2.046 |
| | | NC used for convenience stores, fast food restaurants, and grocery stores | Mean=.960, SD=.935 | Mean=.179, SD=.384 |
| | | NC used for offices, fast food restaurants, and hospitals | Mean=1.760, SD=1.128 | Mean=.702, SD=.935 |
| | | NC used for grocery stores, restaurants, retail stores, convenience stores, bank, and post offices | Mean=.520, SD=.653 | Mean=.219, SD=.451 |

Table 3.4. (Continued)

| Variable | Measurements | | Coding and Descriptive Statistics: Zip Code Level (N=25) | Coding and Descriptive Statistics: Individual Level (N=503) |
|---|---|---|---|---|
| Destination | Ratio: Distance to the closest each destination within a 3km network buffer | Bank | | (ft): Mean=3558.674, SD=1927.401 |
| | | Bar | | 10=up to 0.3 mile, 11=0.3-0.6 mile, 12=0.6-0.9 mile, 13=0.9-1.2 mile, 14=1.2-1.5 mile, 15=1.5-1.8 mile, 16=1.8+ mile (Mean=12.475, SD=1.819) |
| | | Big box retail | | 10=no: 277, 11= have one or more: 226 |
| | | Church | | (logged ft): Mean=7.293, SD=.731 |
| | | Neighborhood/Community shopping center | | 10=up to 0.3 mile, 11=0.3-0.6 mile, 12=0.6-0.9 mile, 13=0.9-1.2 mile, 14=1.2-1.5 mile, 15=1.5-1.8 mile, 16=1.8+ mile (Mean=13.634, SD=1.899) |
| | | Convenience store | | (ft): Mean=2930.044, SD=1850.852 |
| | | Day care center | | (ft): Mean=5290.147, SD=2627.163 |
| | | Fast food restaurant | | (ft): Mean=4036.566, SD=2490.290 |
| | | Fitness center | | 10= up to 0.6 mile, 11=0.6-1.2 mile, 12=1.2-1.8 mile, 13=1.8+mile (Mean=11.789, SD=.980) |
| | | Grocery store | | (logged ft): Mean=7.650, SD=.680 |
| | | Hospital | | (logged ft): Mean=7.627, SD=.718 |
| | | Library | | 10=up to 0.3 mile, 11=0.3-0.6 mile, 12=0.6-0.9 mile, 3=0.9-1.2 mile, 14=1.2-1.5 mile, 15=1.5-1.8 mile, 16=1.8+ mile (Mean=12.849, SD=1.677) |
| | | Mixed use | | 10=up to 0.15 mile, 11=0.15-0.3 mile, 12=0.3-0.6 mile, 13=0.6-1.8 mile, 14= 1.8+mile (Mean=11.429,SD=1.059) |
| | | Museum | | 10= up to 0.6 mile, 11=0.6-0.9 mile, 12=0.9-1.2 mile, 13=1.2-1.8 mile, 14=1.8+ mile (Mean=11.984,SD=1.434) |
| | | Office | | (logged ft) Mean=7.132, SD=.852 |
| | | Post office | | 10=up to 0.6 mile, 11=0.6-0.9 mile, 12=0.9-1.2mile, 13=1.2-1.5 mile, 14=1.5-1.8 mile, 15=1.8+mile (Mean=12.157, SD=1.723) |
| | | Regional shopping center | | 10=no: 90, 11= have one or more:413 |
| | | Restaurant | | (logged ft) Mean=7.415, SD=.797 |
| | | Retail store | | (logged ft) Mean=7.040, SD=.814 |
| | | School | | (logged ft) Mean=7.536, SD=.646 |
| | | Sport facility | | 10=up to 0.3 mile, 11=0.3-0.6 mile, 12=0.6-0.9 mile, 13=0.9-1.2 mile, 14=1.2-1.8 mile, 15=1.8+ mile (Mean=12.394, SD=1.437) |
| | | Theater | | 10= up to 0.6 mile, 11=0.6-1.2 mile, 12=1.2-1.8 mile, 13=1.8+mile (Mean=11.310, SD=1.102) |
| | | Park | | (ft): Mean=2296.320, SD=1644.399 |
| | | Trail | | 11=up to 0.5 mile, 12=0.5-1 mile, 13=1-1.5 mile, 14=1.5-2 mile, 15=2+ mile (Mean=12.636, SD=1.000) |

Table 3.4. (Continued)

| Variable | Measurements | | Coding and Descriptive Statistics | |
|---|---|---|---|---|
| | | | Zip Code Level (N=25) | Individual Level (N=503) |
| Destination | Ratio: Distance to the closest each neighborhood center (NC) within a 3km network buffer | NC used for grocery stores and retail stores | | (logged ft): Mean=7.191, SD=1.237 |
| | | NC used for grocery stores, restaurants, and retail stores | | (logged ft): Mean=7.172, SD=1.233 |
| | | NC used for grocery store and restaurants | | (logged ft): Mean=7.773, SD=1.026 |
| | | NC used for convenience stores, restaurants, and grocery stores | | (logged ft): Mean=3822.683, SD=2568.306 |
| | | NC used for offices and mixed uses | | 11=up to 0.05 mile, 12=0.05-0.15 mile, 13=0.15-0.25 mile, 14=0.25-0.45 mile, 15=0.45-0.85 mile, 16=0.85-1.75, 17=1.75+ mile (Mean=13.465, SD=1.586) |
| | | NC used for sports facilities and schools | | 11=up to 0.5 mile, 12=0.5-1.0 mile, 13=1.0-1.85 mile, 14=1.85+ mile (Mean=12.382, SD=1.047) |
| | | NC used for churches and schools | | (logged ft): Mean=7.317, SD=1.149 |
| | | Number of NC used for offices | | (logged ft): Mean=7.146, SD=1.278 |
| | | NC used for convenience stores, fast food restaurants, and grocery stores | | 11=up to 0.7 mile, 12=0.7-1.3 mile, 13=1.3-1.85 mile, 14=1.85+ mile (Mean=12.429, SD=1.054) |
| | | NC used for offices, fast food restaurants, and hospitals | | 11=up to 0.08 mile, 12=0.08-0.30 mile, 13=0.30-0.60 mile, 14=0.60-1.00 mile, 15=1.00-1.45 mile, 16=1.45-1.85, 17=1.85+ mile (Mean=13.881, SD=1.639) |
| | | NC used for grocery stores, restaurants, retail stores, convenience stores, bank, and post offices | | 10=no: 314, 11= have one or more: 189 |

***** Index measures the mixture status of single family, multi family, retail service, education, institution, office, and other.

The objectively measured infrastructure variables from the GIS measure cover the total street length, average street width, average traffic volume, average traffic speed, the number of bus stops, the number of traffic signals, total sidewalk length, number of street intersections, and mean slope (Table 3.5).

Table 3.5. Descriptive Statistics of Independent Variables: Objectively Measured Infrastructure Built Environmental Variables

| Variable | Measurements | Coding and Descriptive Statistics | |
|---|---|---|---|
| | | Zip Code Level (N=25) | Individual Level (N=503) |
| Street Length | Ratio: Total length of street (ft) | Mean=639622.466, SD=380547.136 | Mean=98989.784, SD=32303.343 |
| Street Width | Ratio: Average number of lanes per way on the street | Mean=1.300, SD=.278 | Mean=1.391, SD=0.296 |
| Traffic Speed | Ratio: Posted traffic speed | Mean=32.177, SD=2.794 | Mean=31.201, SD=2.347 |
| Traffic Volume | Ratio: Average traffic volume | Mean=11289.542, SD=5434.289 | Mean=10915.332, SD=6836.558 |
| Bus Service | Ratio: Number of bus stops | Mean=10839.400, SD=7715.273 | Mean=43.716, SD=27.337 |
| Sign | Ratio: Number of traffic signs (logged count) | Mean=39.280, SD=24.062 | Mean1.906=, SD=1.067 |
| Sidewalk | Ratio: Total sidewalk length (ft) | Mean=2995110.969, SD=10270041.547 | Mean=36180.793, SD=15086.597 |
| Intersection | Ratio: Number of intersections | Mean=720.600, SD=293.146 | Mean=137.779, SD=54.504 |
| Slope | Ratio: Mean slope (%) | Mean=8.185, SD=2.664 | Mean=8.152, SD=3.094 |

The subjectively measured land use variables include neighborhood composition and predominance of housing types, and the data source is the WBC survey (Table 3.6).

Table 3.6. Descriptive Statistics of Independent Variables: Subjectively Measured Land Use Built Environmental Variables

| Variable | Measurements | Coding and Descriptive Statistics | |
|---|---|---|---|
| | | Zip Code Level (N=25) | Individual Level (N=503) |
| Neighborhood Composition | Nominal: 1=neighborhood composition: residential, 2=commercial, 3=mix of residential and commercial | Mean=.367, SD=.135 | 0: 308, 1: 195 |
| Predominant of Housing Type | Nominal: 1=single family homes, 2=apartments or condominiums, 3=mix of single family homes & apartment | Mean=2.170, SD=.351 | 1: 199, 2: 72, 3: 232 |

The subjectively measured infrastructure class variables include eight neighborhood perception variables through the factor analysis: (1) presence of auto-oriented facilities in the neighborhood, (2) presence of destinations in the neighborhood, (3) safety and maintenance of the neighborhood, (4) visual quality of the neighborhood,

(5) presence of amenities for biking and jogging in the neighborhood, (6) social support for walking and biking in the neighborhood, (7) street amenities in the neighborhood, and (8) problems related to automobiles in the neighborhood (Table 3.7). All used data comes from the WBC survey.

Table 3.7. Descriptive Statistics of Independent Variables: Subjectively Measured Infrastructure Built Environmental Variables

| Variable | Measurements | | Coding and Descriptive Statistics | |
|---|---|---|---|---|
| | | | Zip Code Level (N=25) | Individual Level (N=503) |
| Neighborhood Perception | Ratio: Neighborhood perception * | Presence of auto-oriented facilities in the neighborhood | Mean=-.020, SD=.351 | Mean=.0033, SD=0.961 |
| | | Presence of destinations in the neighborhood | Mean=-.039, SD=.290 | Mean=-0.074, SD=.942 |
| | | Safety and maintenance of the neighborhood | Mean=.031, SD=.327 | Mean=0.026, SD=.970 |
| | | Visual quality | Mean=.090, SD=.595 | Mean=-0.100, SD=.971 |
| | | Presence of amenities for biking and jogging | Mean=-.035, SD=.460 | Mean=0.029, SD=1.001 |
| | | Social support for walking and biking in the neighborhood | Mean=-.023, SD=.410 | Mean=0.029, SD=.995 |
| | | Street amenities | Mean=.020, SD=.355 | Mean=-0.072, SD=.912 |
| | | Problems related to automobiles in the neighborhood | Mean=-.077, SD=.371 | Mean=.021, SD=1.000 |

* The ratio used 8 factors from the 32 neighborhood perception questions through the factor analysis.

#### 3.3.3.3. Confounding Variables

As confounding variables are the personal factors and they are classified into walking, biking, the use of transit service, attitudes toward the environment and transportation, physical activity, household characteristics, and individual demographic characteristics (Table 3.8). The walking variable is the total weekly minutes of walking along with dummy variables of walking for recreation, commuting, and to retail services. The biking and use of transit service variables also includes dummy variables of non-biker/ biker and non-transit user/transit user. The attitudes toward the environment and transportation variable uses three factors (e.g. problems of traffic congestion and air pollution, knowledge of physical activity, and preference for walking and biking to solve congestion) captured by factor analysis. The physical activity variable is the level of physical activity at work, total weekly minutes of vigorous and moderate activity, and the usage of exercise equipment at home. The household characteristics variable is the number of cars per household in addition to two kinds of dummy variables such as homeownership and having a dog. The demographic variables includes the individual characteristics of age, gender, ethnicity, education level, marital status, income, vehicle miles traveled, total weekly minutes of sedentary life at home, and the average number of times of eating out per week.

Table 3.8. Descriptive Statistics of Confounding Variables

| Class | Variable | Measurements | | Coding and Descriptive Statistics: Zip Code Level (Zip code, N=25) | Coding and Descriptive Statistics: Individual Level (Individual, N=503) |
|---|---|---|---|---|---|
| Walking | Waking minutes | Ratio: Total weekly minutes of walking (categorical): 11=0 minute, 12=1-59 minutes, 13= 60-149 minutes, 14=150-209 minutes, 15= 210 + minutes | | Mean=13.057, SD=.447 | Mean=13.175, SD=1.263 |
| | Recreation Walk | Nominal: Walk for recreation: 0=non-walker, 1=walker | | Mean=.725, SD=.099 | 0: 127, 1: 376 |
| | Transportation Walk | Nominal: Walk for commuting and to retail services:0=non-walker, 1=walker | | Mean=.618, SD=.157 | 0: 160, 1: 343 |
| Biking | Biking | Nominal: 0=Non-biker, 1=biker | | Mean=.206, SD=.115 | 0: 390, 1:107 |
| Use of transit Service | Transit Use | Nominal: 0=non-transit user, 1=transit user | | Mean=.310, SD=.140 | 0: 324, 1: 179 |
| Attitude toward Env./ Transportation | Attitude toward Environment/Transportation | Ratio: Attitude toward the environment and transportation* | Problems of traffic congestion and air pollution | Mean=-.006, SD=.352 | Mean=0.044, SD=0.965 |
| | | | Knowledge of physical activity | Mean=.026, SD=.204 | Mean=-0.012, SD=0.995 |
| | | | Preference for walking and biking to solve congestion | Mean=.000, SD=.380 | Mean=0.077, SD=0.981 |
| Physical Activity | Physical Activity at Work | Ordinal: Phase of physical activity at work: 1=don't walk, 2=mostly sitting or standing, 3=mostly walking, 4=mostly heavy labor | | Mean=1.995, SD=.200 | Mean=1.972, SD=.853 |
| | Vigorous Activity | Ordinal: Total weekly minutes of vigorous activity, (categorical): 11=0hr, 12=1-149hrs, 13=150 + hrs | | Mean=11.829, SD=.230 | Mean=11.859, SD=.834 |
| | Moderate Activity | Ratio: Total weekly minutes of moderate activity (logged) | | Mean=5.348, SD=.315 | Mean=5.375, SD=1.016 |
| | Exercise Equipment | Nominal: Using exercise equipment at home:0=no, 1=yes | | Mean=.323, SD=.120 | 0: 354, 1: 149 |
| Household Characteristics | Home Ownership | Nominal: 0=no, 1=yes | | Mean=.606, SD=.179 | 0: 184, 1: 319 |
| | Car Ownership | Ratio: Number of cars per household | | Mean=1.509, SD=.283 | Mean=1.533, SD=.940 |
| | Dog Ownership | Nominal: Having a dog: 0=no, 1=yes | | Mean=.194, SD=.102 | 0: 404, 1: 99 |
| Demographics/ Individual Characteristics | Age | Ratio: Age: 1=18-24yrs, 2=25-34yrs, 3=35-44yrs, 4=45-54yrs, 5=55-64yrs, 6=65-74yrs, 7=75+yrs | | Mean=3.781, SD=.415 | Mean=3.831, SD=1.585 |
| | Gender | Nominal:0=male, 1=female | | Mean=.496, SD=.138 | 0: 243, 1: 260 |
| | Race | Nominal: 0=nonwhite, 1=white | | Mean=.888, SD=.113 | 0: 50, 1: 453 |
| | Education | Ordinal: Phase of education: 1=never attended school or only kindergarten, 2=grades 1 through 8 (elementary), 3=grades 9 through 11 (some high school), 4=grade 12 or GED (high school graduate), 5=college 1 to 3 yrs (some college or technical school), 6=college 4yrs or more (college graduate), 7=graduate school or more | | Mean=5.628, SD=.371 | Mean=5.718, SD=.949 |
| | Marital Status | Nominal: Marital status: 11=married or a member of an unmarried couple, 12=divorce, widowed, or separated, 13=never married | | Mean=11.781, SD=.280 | 11: 249, 12: 120, 13: 134 |

Table 3.8. (Continued)

| Class | Variable | Measurements | Coding and Descriptive Statistics | |
|---|---|---|---|---|
| | | | Zip Code Level (Zip code, N=25) | Individual Level (Individual, N=503) |
| Demographics/ Individual Characteristics | Income | **Ordinal:** Average yearly household income: 1=~\$9,999, 2=\$10,000~\$14,999, 3= \$15,000~\$19,999, 4=\$20,000~\$24,999, 5=\$25,000~\$34,999, 6=\$35,000~\$49,999, 7=\$50,000~\$74,999, 8=\$ 75,000+ | Mean=6.307, SD=.433 | Mean=6.380, SD=1.436 |
| | VMT | **Ordinal:** Vehicle miles traveled, Categorical: 11=0 mile, 12=1-249 miles, 13=250-499 miles, 14=3, 500-749 miles, 15=750-999 miles, 16=1000-1249 miles, 17=1250-1499 miles, 18=1500-1749 miles, 19=1750+miles | Mean=14.451, SD=.625 | Mean=14.342, SD=1.914 |
| | Sedentary life | **Ratio:** Total weekly hours of sedentary life at home | Mean=3.070, SD=.228 | Mean=3.056, SD=.823 |
| | Eating Out | **Ratio:** Number of eating outs per week | Mean=3.610, SD=.995 | Mean=3.636, SD=3.137 |

* The ratio used 3 factors from the 11 attitude towards the environment questions through the factor analysis

For the zip code level correlation analysis, distances to 24 destinations and 11 neighborhood centers are eliminated from the variable list because of unavailable data (e.g. distance measured to the destination is only available at the individual level), while all variables are used for the multiple regression model measuring individual health disparity and hot spot analysis. Thus, 84 variables are considered for the zip code correlation test. And 119 variables (e.g. 84 available destination distance measures + 24 unavailable destination distance measures + 11 neighborhood centers distance measures) are considered for the individual health disparity multiple regression model and the hot spot analysis.

## 3.4. Data Analysis

### 3.4.1. Aim One

Descriptive statistics and Gini coefficients are used to describe the levels of nationwide health disparity in United States. This step diagnoses the problem by comparing the current health disparity status across the US. Then, the historic trends of health disparities from 1995 to 2004 help illustrate the rates of changes in health disparity over time and anticipate future trends.  This helps alert the public and policy makers to the seriousness of the problem and to help develop strategies to effectively cope with health disparity in the future.

### 3.4.2. Aim Two

A hot spot is defined in this study as a geographic cluster of higher than average intensity in characteristics. It is popularly used in identifying concentrations of criminal events (Chainey and Ratcliffe, 2005; Xue and Brown, 2006; Grubesic, 2006) and natural disaster incidents (Dilley et al., 2005). GeoDa (Anselin, 2004; Anselin, Syabri, and Kho, 2006), collection of software tools designed for exploratory spatial data analysis, is used to identify geographic patterns and magnitudes of spatial autocorrelation identifying areas with high levels of health disparity.

#### 3.4.2.1. Disparity Measurement for Individual Health Disparity

For the disparity measurement for individual health disparity, the minimum number of samples within each spatial unit is ten. Only 242 and 407 out of the total 608 survey respondents have more than ten individuals within 1 km- and 2 km- buffers, respectively. The greater the buffer size, the more individuals will have at least ten neighbors within each spatial unit to calculate the Gini coefficient of each individual's health disparity. However, spatial correlations happen when the buffer size becomes larger. Therefore, it is necessary to decide on an optimal buffer size which can maximize the sample size and minimize overlap among the buffers together. After several attempts at finding an optimal buffer size, the 3 km buffer is selected. The 3km buffer is built around each respondent (N=503) in this study (Figure 3.4).

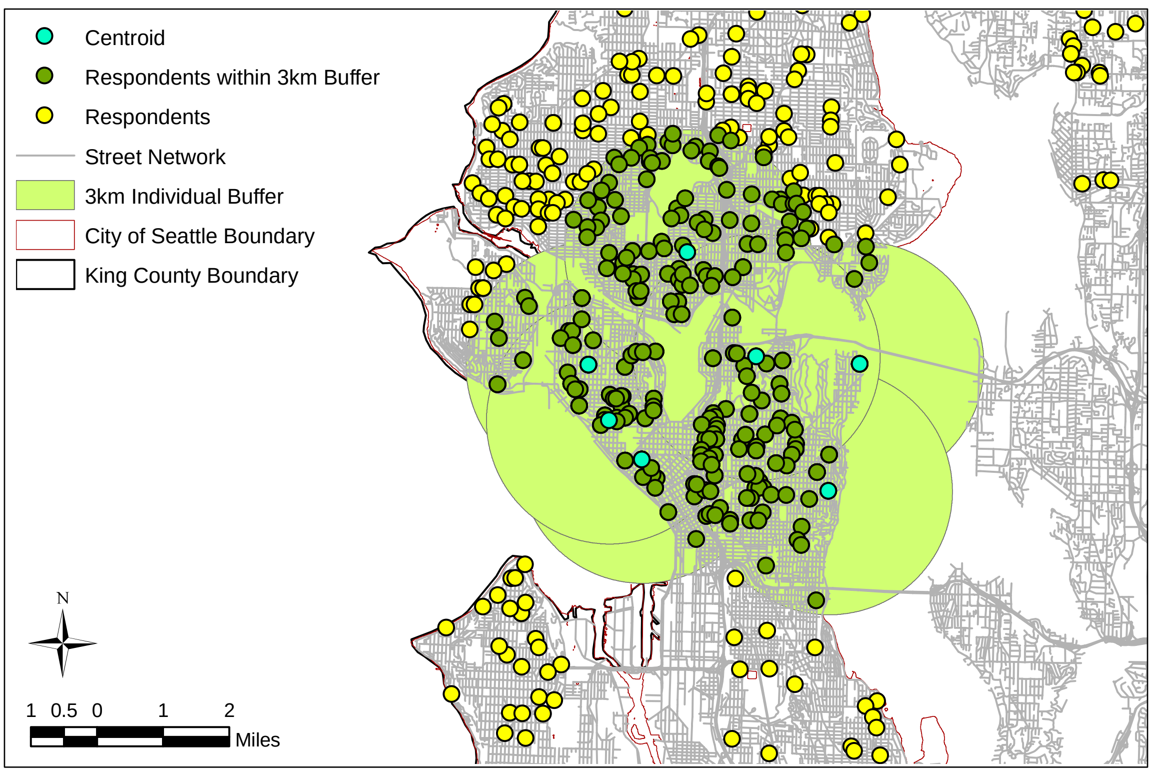


Figure 3.4. Disparity Measurement for the Study: Individual Health Disparity with 3km Buffer of Each Respondent

**3.4.2.2. Spatial Autocorrelation Measures**

Moran's I values ranging from -1 to 1, maximum negative to positive autocorrelations, are used to measure the levels of spatial autocorrelation. The equation of Moran's I is as follows.

$$I = \frac{n\sum\sum w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{W\sum(y_i - \bar{y})^2}$$

where, $w_{ij}$ the elements of the spatial weight matrix, W
$y_i$ : Gini coefficient of the health indicator (e.g. health status, BMI) in region i
$y_j$ : Gini coefficient of the health indicator in region j
$\bar{y}$ **:** mean of all $y$ observations (Gini coefficients in health status and BMI)
$n$ : total $y$ observations (e.g. $n$=503)

Moran's I spatial autocorrelation statistic is the slope in the scatter plot which shows the original variable (health disparity) on the horizontal axis and the spatial lag of the variable (average health disparity of neighbors) on the vertical axis. Moran scatter plots divide the area into four quadrants and visually show the positive autocorrelation in the upper right (high-high, hot spot) and the lower left (low-low, cold spot) quadrants and negative autocorrelation in the lower right (high-low, outlier) and upper left (low-high, outlier) quadrants. Local Indicator of Spatial Association (LISA) maps are used to measure the spatial clustering. Hot spots are areas with greater variances in health disparity among neighboring individuals and cold spots mean the areas with lower health disparity with similar neighbors.

### 3.4.2.3. Definition of Neighbors

To measure individual spatial autocorrelations, the 4-nearest and 10-nearest neighbors and 3km distance (distance lags of 3km) methods are employed for constructing the spatial weight matrices which define the boundary of the neighbors (Figure 3.5). There is no previous suggestion available to guide the selection of specific parameters for this study. So, several test results show 4-nearest and 10-nearest neighbors and 3km distance methods have the best fir for this study.

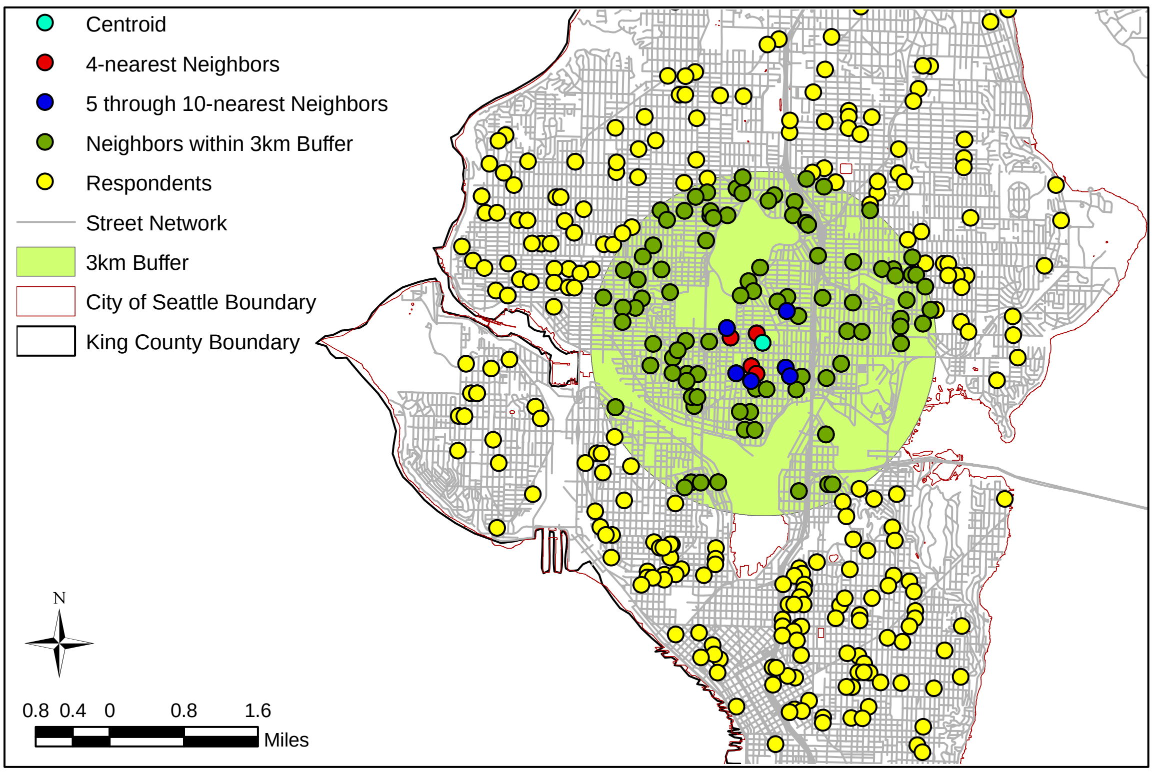


Figure 3.5. Definition of Neighbors (4 and 10-Nearest Neighbors and 3km Distance)

The 4-nearest weight matrix calculates the spatial autocorrelation with the 4-nearest neighbors while the 10-nearest weight includes the10-nearest respondents as neighbors. The 3km distance weight considers all respondents within a 3km buffer as neighbors. Thus, this study employed three kinds of neighboring methods (e.g. 4-nearest, 10-nearest, and 3km distance measures) to calculate the spatial autocorrelation.

#### 3.4.2.4. Built Environmental and Personal Factors Influence on Hot Spots

To examine the significant variables for the hot spots, ANOVA and a post-hoc multiple comparison among the groups are used. Respondents (N=503) are classified into hot spots, cold spots (areas with lower health disparity), and outlier groups to identify the significant factors associated with the formations of hot and cold spots.

### 3.4.3. Aim Three

#### 3.4.3.1. Zip Code Level

For a description of health disparity at the zip code level, 25 out of 50 zip codes are included based on having the minimum sample size of ten. The Pearson correlation coefficient (R) is used to identify the relationship between the built environment and health disparity.

#### 3.4.3.2. Individual Level

Before and during the modeling process, outliers based on the criteria 3 standard deviation are detected and eliminated because they distort and bias the appropriate structure of the model. The proposed study includes many spatial attributes as explanatory variables. Empirical studies (e.g. Shin, 2002) have reported that there exist a variety of dependent relationships among the spatial variables. Therefore, the proposed model may violate the assumption of 'no strong collinearity among the independent variables.' Because of this, particular attention is paid to address the collinearity problem. The assumptions of the model are verified through various methods including a correlation matrix, scatterplot matrix, analysis of residuals, VIF (variance inflation factor), and tolerance. Multiple regression models are used as the preferred model for this study, but before finalizing the models several tests are performed to ensure their reliability and validity. These tests include the examination of the heteroskedasticity, normality of the residuals, and spatial autocorrleations.

The 119 factors considered as independent variables are too numerous and there may be strong collinearity among them. However, theoretically important variables may be eliminated from the model if variable selection decisions are made based on only the statistical testing of assumptions.

To build an effective regression model, the process shown Figure 3.6 is used to handle the data: (1) set a selected variables list relevant to and effective on a dependent variable from Tables 3.4 through 3.8 based on the literature and hypotheses, (2) test a correlation with the dependent variable to verify the most important predictors, (3) test a correlation within a category to eliminate the collinearity from the selected significant variables in the second step, and then develop the best selected independent variables list, (4) test a multiple regression model with the selected independent variables from the third step with adding variables from the Tables 3.4 through 3.8, (5) check the model fit and collinearity among the variables with other assumption checks. Return to (4) until satisfied with the model fit and all assumptions, (6) compare the OLS and spatial regression models to evaluate the best model, and (7) develop the final multiple regression model.

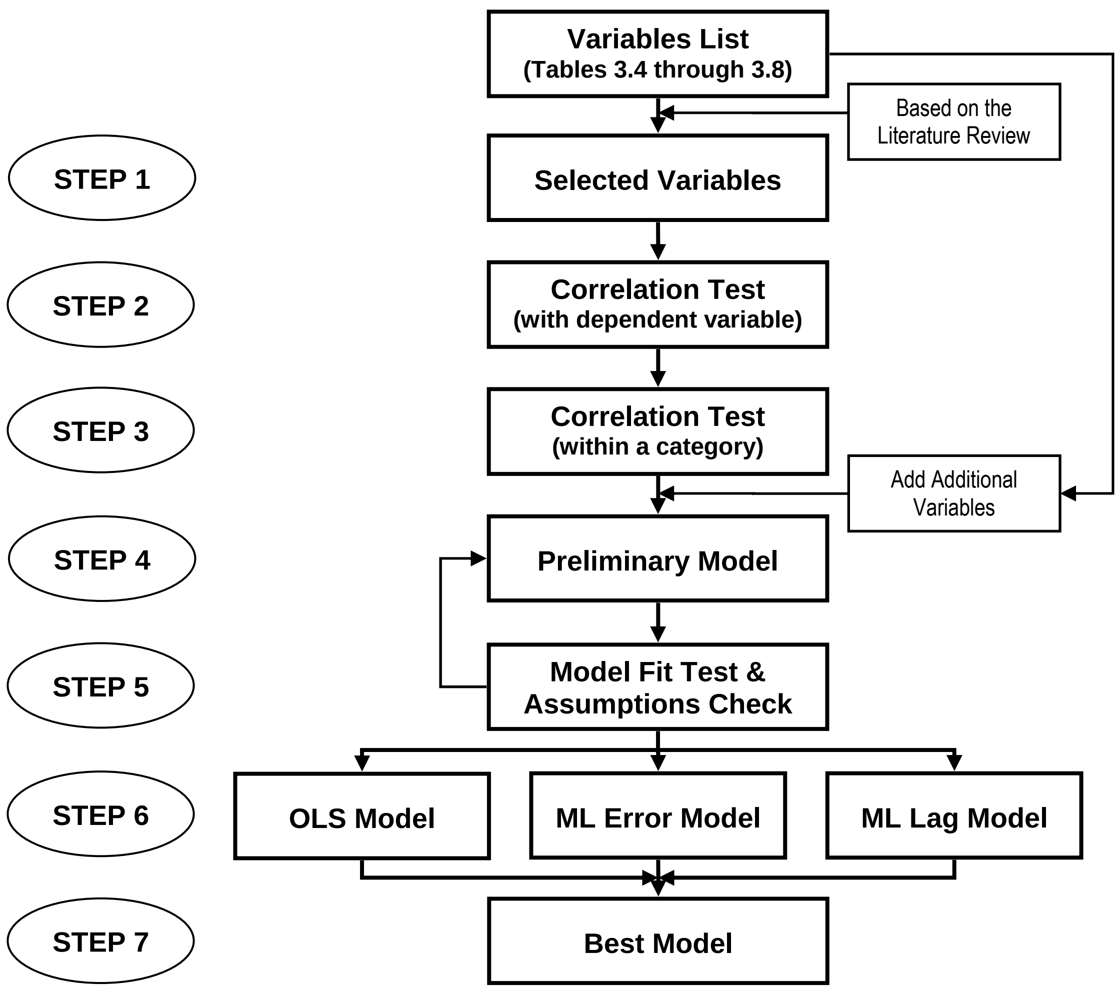


Figure 3.6. Analysis Process at the Individual Level

A logistic regression model is used to measure health status because the variable is dichotomous, as opposed to continuous; the obesity regression model uses Ordinary Least Squares (OLS) regression. In addition to the logistic and OLS regression models, a spatial regression model is used for the multivariate statistical analysis in identifying significant built environmental correlates of health status, obesity, and health disparity.

The Moran's I statistics from the hot spot analysis are used to further test the existence of spatial dependence. If the tests confirm the presence of autocorrelations, alternative models such as the spatial regression model (instead of OLS) will be used.

There are two types of spatial dependence (e.g. Maximum likelihood [ML] spatial lag and maximum likelihood [ML] spatial error) to be observed in practice and considered in this dissertation. The ML error model is used when the different error terms are correlated with each other; the ML spatial lag model is used when the dependent variable $Y_i$ is influenced by the independent variables $X_i$ and $X_j$, simultaneously as shown in Figure 3.7.

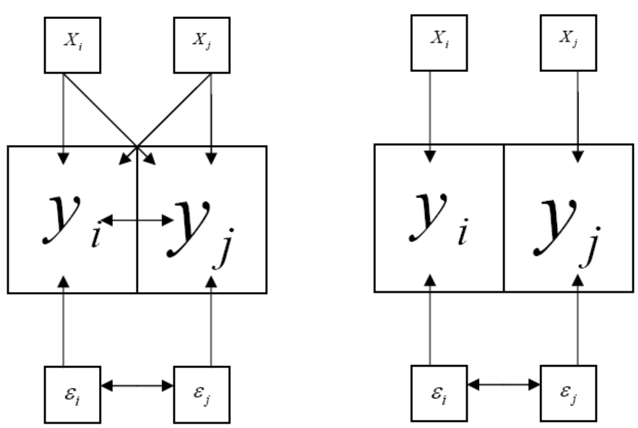


Figure 3.7. ML Spatial Lag and ML Spatial Error (Adapted from Baller et al., 2001)

The following are the model equations:

Spatial lag model:
$y = \rho W_y + X\beta + \varepsilon$

y: dependent variable
X: independent variable
$\beta$ : regression coefficient
$\varepsilon$ : random error term
$\rho$ : spatial autoregressive coefficient
$W_y$ : spatially lagged dependent variable

Spatial error model:
$y = X\beta + \varepsilon, \qquad \varepsilon = \lambda W_\varepsilon + \xi$

y: dependent variable
X: independent variable
$\beta$ : regression coefficient
$\varepsilon$ : random error term
$\lambda$ : autoregressive coefficient
$W_\varepsilon$ : spatial lag for the error
$\xi$ : normal distribution with mean 0 and variance $\sigma^2 I$

# CHAPTER IV

# RESULTS

Chapter IV consists of three sections including the results for the three specific aims of the study. Section 4.1 investigates the magnitudes and longitudinal trends of health disparity in US at the state level and Section 4.2 explores the spatial autocorrelation in disparity and addresses the built environmental factors on clusters of higher levels in disparity. Section 4.3 examines the built environmental correlates of obesity, health status, and disparity at the zip code and individual levels.

## 4.1. Aim One

The specific goal of aim one is to examine the magnitude and historic trends in US health disparity by state between 1995 and 2004, and to identify the effects of socioeconomic factors on health disparity. Perceived health status and BMI from the BRFSS as health indicators and the Gini coefficient as a measurement are used to discuss health disparity in this chapter. The ANOVA test is used to identify the regional differences of health disparity and a bivariate correlation analysis is used to examine the relationship between socioeconomic factors and disparity. The GIS maps and the longitudinal graphs describe the historic trends in health disparity.

### 4.1.1. Overall Disparity Trends

All states had a positive net increases between 1995 and 2004 in the obesity disparity and all but four states (District of Columbia, -0.01308; Hawaii, -0.00445; North Dakota, -0.00417; Delaware, -0.00010) showed an increase in the health status disparity. In addition, all States annually increased the disparity for both indicators except for the health status disparities in three states, including the District of Columbia (Annual increase rate= -0.989%), Hawaii (-0.337%), and North Dakota (-0.202%).

As shown in Figure 4.1[3], the overall trend of health disparity gradually intensified between 1995 and 2004, consistent with the obesity trend reported by the CDC in 2005. Note that different classification methods were used to separate each color group between health disparity and obesity trends; however, both presented similar patterns of increase over time. In addition to the overall increasing trend, there are differences in the spatial distributions of disparity. States with higher disparities clustered in the south, whereas States with lower disparities were more commonly found in the west and/or north central regions. Additional health disparity maps including all ten years between 1995 and 2004 were presented in the Appendix 1.

[3] Criteria to classify categories for each health disparity are 20%, 40%, 60%, 80%, and 100% percentiles of all computed values during empirical period, 1995-2004.

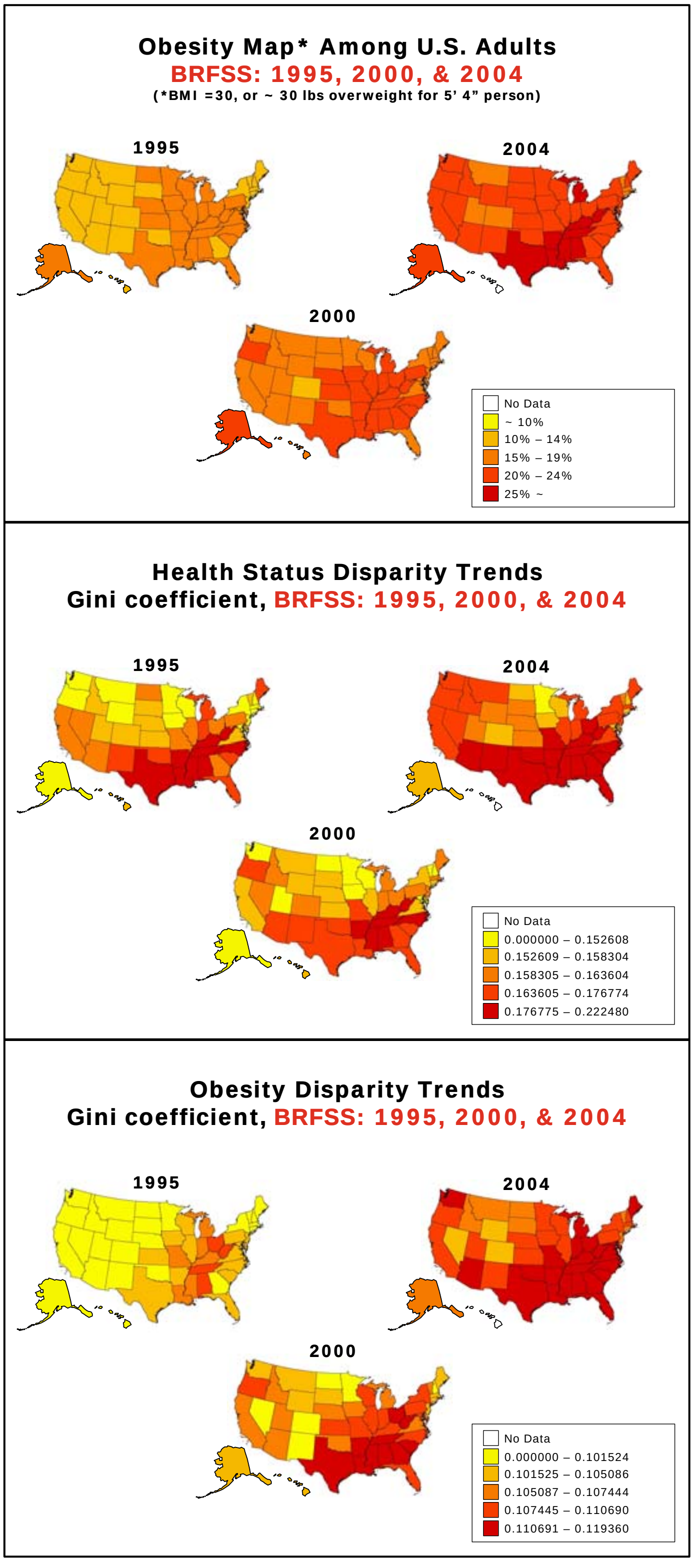


Figure 4.1. Health Disparity and Obesity Trends

### 4.1.2. Regional Differences in Disparity and Disparity Trends

To test the potential regional differences in health disparity, the 51 states (counting the District of Columbia) are grouped into four census regions (Northeast, Midwest, South, and West) and differences among these four regions are examined using ANOVA. The results are summarized with longitudinal trends and spatial differences among the four census regions in the following sections.

#### 4.1.2.1. Longitudinal Disparity Trends among Census Region

All four census regions experienced a gradual increase in both disparities (e.g. health status and obesity disparities) between 1995 and 2004. Descriptive statistics in Table 4.1 shows that the mean disparity values have increased over time.

Table 4.1. Descriptive Statistics of Health Disparities (1995, 2000, and 2004)

| Health Disparity (Gini coefficient) | Year | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Health Status Disparity | 1995 | 50 | .16222 | .01455 | .00206 | .15809 | .16636 |
| | 2000 | 51 | .16322 | .01420 | .00199 | .15923 | .16722 |
| | 2004 | 50 | .17194 | .01620 | .00229 | .16733 | .17654 |
| Obesity Disparity | 1995 | 50 | .10126 | .00424 | .00060 | .10005 | .10246 |
| | 2000 | 51 | .10723 | .00445 | .00062 | .10598 | .10849 |
| | 2004 | 50 | .11071 | .00435 | .00061 | .10947 | .11194 |

Unavailable state data: District of Columbia (1995) and Hawaii (2004)

Longitudinal graphs visually confirm again that both health status disparity and obesity disparity (Figure 4.2) continually increased between 1995 and 2004. One more notable point from the longitudinal graphs is that the South has greater disparity than the other three census regions. Although there were differences in magnitudes between health status and obesity disparities, the South is clearly higher than the other regions. Further investigation for spatial differences among the four census regions is discussed in the next section.

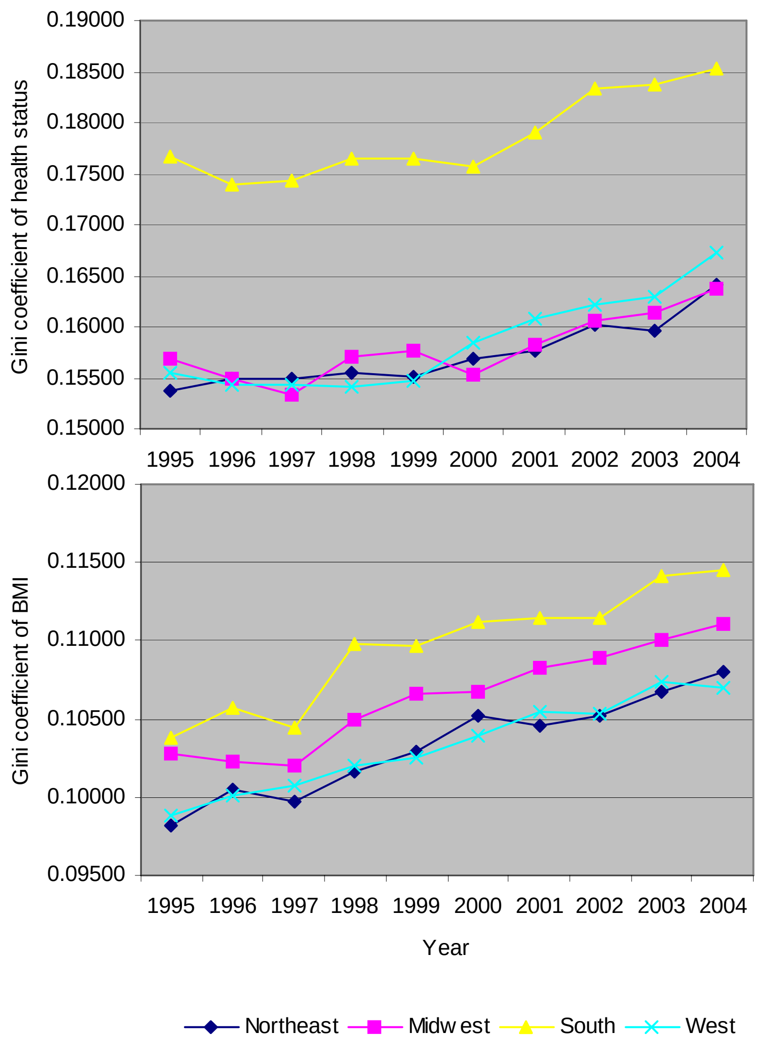


Figure 4.2. Health Status and Obesity Disparities between 1995 and 2004

However, there were no sufficient differences among the four census regions in net increases and in average annual increases in rates of disparities between 1995 and 2004. Thus, it can be concluded that even though disparities in the South were relatively higher than in the other regions, the levels of disparity did not grow faster than in other regions between 1995 and 2004. There were significant yearly differences in disparities in health status between 2000 and 2004, in obesity between 1995 and 2000, and in obesity between 2000 and 2004 (Table 4.2).

Table 4.2. ANOVA Table for Comparing Yearly Differences in Health Disparity

| Group | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Health Status Disparity in 1995 and 2000 (Gini coefficient) | Between Groups | .000 | 1 | .000 | .121 | .728 |
| | Within Groups | .020 | 99 | .000 | | |
| | Total | .020 | 100 | | | |
| Health Status Disparity in 2000 and 2004 (Gini coefficient) | Between Groups | .002 | 1 | .002 | 8.275 | .005 |
| | Within Groups | .023 | 99 | .000 | | |
| | Total | .025 | 100 | | | |
| Obesity Disparity in 1995 and 2000 (Gini coefficient) | Between Groups | .001 | 1 | .001 | 47.737 | .000 |
| | Within Groups | .002 | 99 | .000 | | |
| | Total | .003 | 100 | | | |
| Obesity Disparity in 2000 and 2004 (Gini coefficient) | Between Groups | .000 | 1 | .000 | 15.730 | .000 |
| | Within Groups | .002 | 99 | .000 | | |
| | Total | .002 | 100 | | | |

#### 4.1.2.2. Spatial Differences in Disparity among Census Regions

According to Figure 4.2, the South showed the highest disparity level among the four census regions, especially in health status disparity, while the other three had similar magnitudes and net increases in Gini coefficients. However, magnitude differences of obesity disparity among the four census regions were relatively small, even though the South was still the most acute in disparity. Further, the health disparity in the Midwest, while lower than the South, was clearly higher than the Northeast and the West when measured with obesity disparity. Thus, the regions can be divided into two groups based on health status disparity, the South and the other three regions; the obesity disparity can be classified into three groups, including the South, the Midwest, and the other two regions combined. Table 4.3 verifies that disparity in the South was relatively higher than other regions.

Table 4.3. Descriptive Statistics of Census Regional Health Disparities (2004)

| Health Disparity (Gini coefficient) | Census Region | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Health Status Disparity in 2004 | Northeast | 9 | .16406 | .00658 | .00219 | .15900 | .16911 |
| | Midwest | 12 | .16364 | .01018 | .00294 | .15717 | .17011 |
| | South | 17 | .18525 | .01903 | .00462 | .17546 | .19503 |
| | West | 12 | .16729 | .00914 | .00264 | .16148 | .17309 |
| | Total | 50 | .17194 | .01620 | .00229 | .16733 | .17654 |
| Obesity Disparity in 2004 | Northeast | 9 | .10803 | .00213 | .00071 | .10639 | .10967 |
| | Midwest | 12 | .11104 | .00397 | .00115 | .10851 | .11356 |
| | South | 17 | .11452 | .00298 | .00072 | .11299 | .11606 |
| | West | 12 | .10698 | .00292 | .00084 | .10512 | .10884 |
| | Total | 50 | .11071 | .00435 | .00061 | .10947 | .11194 |

Unavailable state data: Hawaii (2004)

To test the statistical significance in the differences in the health disparity measures across different census regions, ANOVA is used. Before running ANOVA, several tests were performed to ensure that the data meet the assumptions of ANOVA.

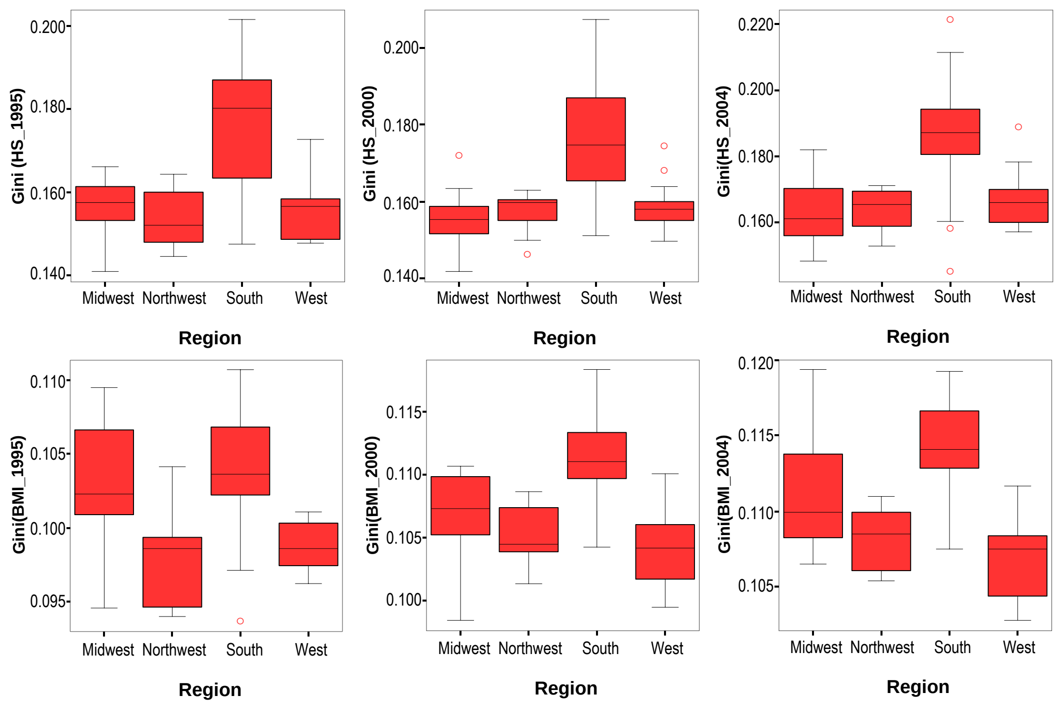


Figure 4.3. Box Plots of Health Status Disparities (Top) and Obesity Disparities (Bottom) in 1995, 2000, and 2004

The box plots in Figure 4.3 display four outliers based on the 3 standard deviation criteria in each disparity in 2000 health status and in 2004 health status out of 51 and 50 respectively; there were no outliers in BMI except for one in 1995. The normal probability plots in health status indicated that a few residuals were somewhat deviant from the fitted line, whereas the BMI showed concentration of the residuals around the straight line. Further, the tests of normality in health status had p-values equal to or less than 0.003, which indicates a strong departure from normality. One the other hand, the tests of normality in BMI yielded p-values greater than 0.200, showing strong support for the normality of the residuals. Thus, it is assumed in the analyses that the data in health status has a non-normal distribution and the data in BMI had a normal distribution.

For the obesity disparity measure, Levene's test was used to further verify the assumption of equality of population variance. Because the p-values of disparity in obesity were at least greater than 0.100 for all years, the standard deviations of the four census regions could be considered equal in the analysis. Thus, ANOVA was used to test for statistically significant differences in obesity disparity among the four census regions.

ANOVA for comparing means among the census regions demonstrates that the census regions were not equal in obesity disparity. As the health status disparity had a non-normal distribution, a nonparametric alternative, the Kruskal-Wallis Test, was used. From the p-values were equal to or less than 0.002, it can be concluded that at least one of the four groups of census regions differs with respect to health disparity in health status.

A post hoc test was used to investigate which census region was different from the others. Tukey's tests were selected and the results of homogeneous subsets of health status and obesity disparities are presented in Tables 4.4 and 4.5, respectively. The results show that groups by health status disparity could include two, the South and the rest (Northeast, West, and Midwest together), and disparities in the South were higher than those in the other regions.

Table 4.4. Homogeneous Subsets of Health Status Disparity (Gini Coefficient)

| 1995 | | | | 2000 | | | | 2004 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Census Region | N | Subset for alpha = .05 | | Census Region | N | Subset for alpha = .05 | | Census Region | N | Subset for alpha = .05 | |
| | | 1 | 2 | | | 1 | 2 | | | 1 | 2 |
| Northeast | 9 | .1537 | | Midwest | 12 | .1554 | | Midwest | 12 | .1636 | |
| West | 13 | .1554 | | Northeast | 9 | .1569 | | Northeast | 9 | .1641 | |
| Midwest | 12 | .1568 | | West | 13 | .1585 | | West | 12 | .1673 | |
| South | 16 | | .1766 | South | 17 | | .1758 | South | 17 | | .1852 |
| Sig. | | .899 | 1.000 | Sig. | | .906 | 1.000 | Sig. | | .909 | 1.000 |

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 11.981 (1995), 12.114 (2000), and 11.883 (2004).
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Likewise, the obesity disparities in the South were clearly higher than in other regions. The Midwest showed the second highest level of health disparity. It is consistent with what was observed from the longitudinal trends in Figure 4.2. As a result, the most notable points confirmed from the longitudinal trends and the ANOVA are that disparities have increased in all census regions, and disparities in the South are significantly higher than the other regions.

Table 4.5. Homogeneous Subsets of Obesity Disparity (Gini Coefficient)

| 1995 | | | | 2000 | | | | 2004 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Census Region | N | Subset for alpha = .05 | | Census Region | N | Subset for alpha = .05 | | Census Region | N | Subset for alpha = .05 | | |
| | | 1 | 2 | | | 1 | 2 | | | 1 | 2 | 3 |
| Northeast | 9 | .0983 | | West | 13 | .1039 | | West | 12 | .1070 | | |
| West | 13 | .0988 | | Northeast | 9 | .1052 | | Northeast | 9 | .1080 | .1080 | |
| Midwest | 12 | | .1028 | Midwest | 12 | .1067 | | Midwest | 12 | | .1110 | |
| South | 16 | | .1038 | South | 17 | | .1112 | South | 17 | | | .1145 |
| Sig. | | .980 | .899 | Sig. | | .204 | 1.000 | Sig. | | .842 | .101 | 1.000 |

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 11.981 (1995), 12.114 (2000), and 11.883 (2004).
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

For the individual states as of 2004, Kentucky (Gini coefficient = 0.22142), Mississippi (0.21150), West Virginia (0.19897), Alabama (0.19827), and Tennessee (0.19449) were rated the top five in the health status disparity; Ohio (0.11935), Mississippi (0.11924), Alabama (0.11847), Tennessee (0.11769), and Louisiana (0.11745) in the obesity disparity (Table 4.6). From the top 10 states in both the obesity and health status disparity values, all but three states including New Mexico (West), Ohio (Midwest), and Missouri (Midwest) were from the South. Likewise, all states with more than 25 % BMI belonged to the South with the only exception being Michigan (Midwest). Most of the states ranked high in disparity had the prevalence of adult obesity at 25% or greater.

Table 4.6. Top 10 States in Disparity and Obesity in 2004

| Obesity Rates ≥25%* (Source: CDC) | Order | Health Status Disparity | Obesity Disparity |
|---|---|---|---|
| Alabama<br>Arkansas<br>Kentucky<br>Louisiana<br>Michigan<br>Mississippi<br>Tennessee<br>Texas<br>West Virginia | 1st | Kentucky | Ohio |
| | 2nd | Mississippi | Mississippi |
| | 3rd | West Virginia | Alabama |
| | 4th | Alabama | Tennessee |
| | 5th | Tennessee | Louisiana |
| | 6th | Oklahoma | West Virginia |
| | 7th | Arkansas | Georgia |
| | 8th | New Mexico | Missouri |
| | 9th | North Carolina | Kentucky |
| | 10th | Louisiana | Oklahoma |

Note) * The CDC reported that nine states without order had obesity prevalence rates equal to or greater than 25%.

To better capture the disparity trends, all states were divided into quintiles from most equal to unequal states. GIS maps are used to visually demonstrate the relative magnitudes in disparity across the United States (Figure 4.4).

The obesity map from the CDC was added to help compare the two disparity quintile maps with obesity status. Note that the obesity map was classified by the prevalence rate while both health disparity maps were sorted by quintile. Both the nine states with the obesity prevalence of 25% or greater and the top 10 highest-ranking states in disparity tended to be agglomerated in the South.

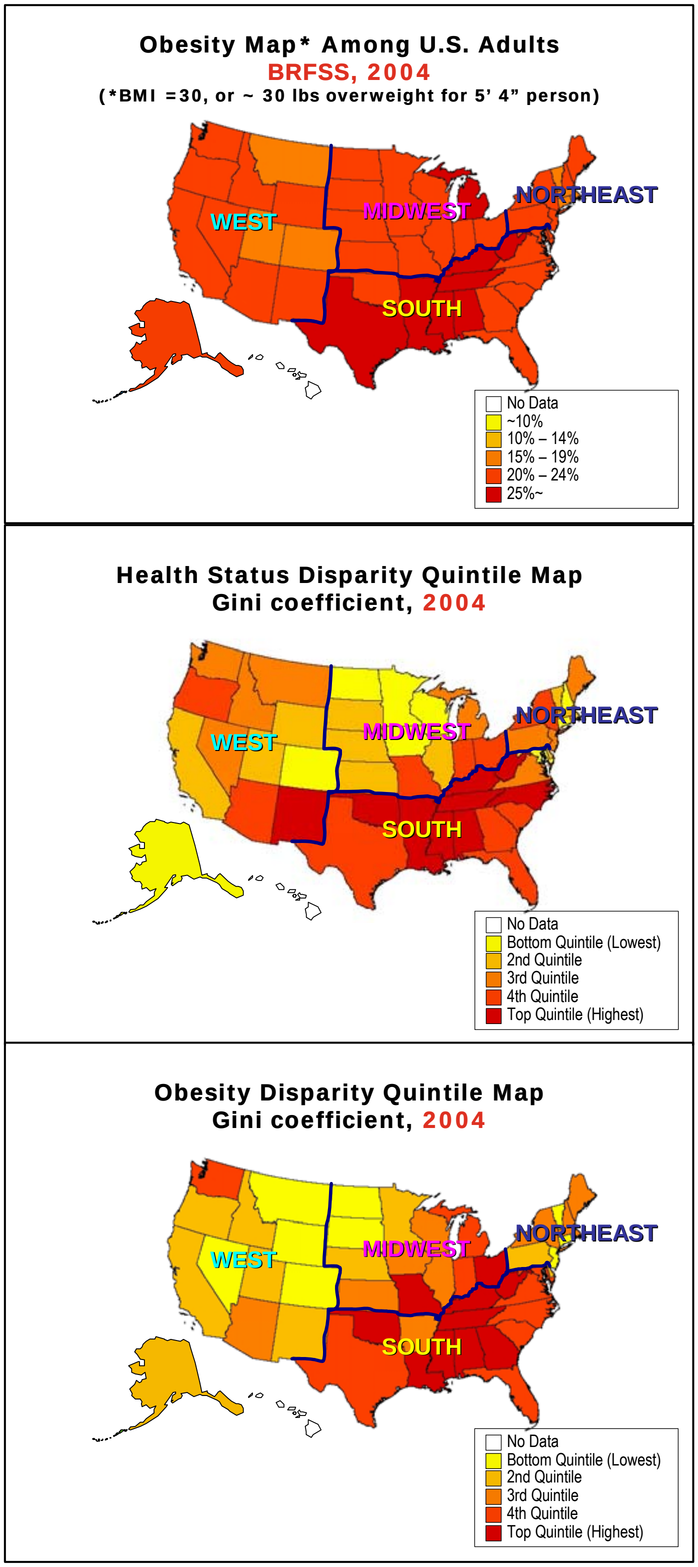


Figure 4.4. Quintile Map

### 4.1.3. Correlation between Disparity and Selected Socioeconomic Characteristics of Each State

The above findings raise the question of what factors cause increasing magnitudes and spatial differences in health disparity. Based on the previous literature, there should be a strong correlation between health outcomes and socioeconomic variables. Specifically, many empirical studies have found that socioeconomic status is a key factor which influences health disparity. Thus, the purpose of this empirical study is to identify the relationship between disparity and the selected socioeconomic factors.

After controlling for demographic covariates, disparity in health status had significant negative associations with the percentage of those with high school education or higher level, median household income, and the percentage of the population using public transportation; it was positively correlated with the percentage of the population below the poverty level in the state (Table 4.7). Disparity in obesity was negatively correlated with the percentage of high school education or higher level, median household income, and the percentage of white population; it was positively correlated with the percentage of population below the poverty level. Variables that did not show any significant association with health disparity included population density, median age, and car ownership. States with higher health disparities were more likely to be associated with lower education levels, lower income, and higher proportions of citizens living below the poverty line.

Table 4.7. Correlation Test (N=50)

| | | Gini coefficient of health status | Gini coefficient of BMI |
|---|---|---|---|
| Median age | Pearson R | .019 | -.010 |
| | p-value | .893 | .946 |
| % of high school + | Pearson R | -.772** | -.616** |
| | p-value | .000 | .000 |
| Median income per HH | Pearson R | -.628** | -.392** |
| | p-value | .000 | .005 |
| % of pop below poverty | Pearson R | .642** | .473** |
| | p-value | .000 | .001 |
| % of no vehicle pop | Pearson R | -.122 | .140 |
| | p-value | .400 | .333 |
| Pop density | Pearson R | -.263 | .083 |
| | p-value | .065 | .564 |
| % of pop using public trans | Pearson R | -.303* | -.019 |
| | p-value | .033 | .898 |
| % of white pop | Pearson R | -.120 | -.305* |
| | p-value | .405 | .031 |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Note) Unavailable state data: Hawaii (as of 2004)

### 4.1.4. Conclusion

In summary, the results of aim one of this study yielded four main points: (1) the overall trend of health disparity had increased continuously from 1995 to 2004, (2) disparity in the South was significantly higher than in the other regions, (3) most high ranked states in disparity had the prevalence of obesity at 25 % or greater, and (4) selected SES variables (e.g. education level, income, and population below the poverty level) correlated with disparity. This study further provides a basis for more detailed and extensive investigations into better understanding the environmental and socioeconomic conditions associated with health disparity, and to develop policy recommendations for reducing health disparity in the US from the urban/transportation planning and public health perspectives. Future studies should include other urban areas and various rural communities, as well as more diverse population groups.

### 4.2. Aim Two

This section analyzes the spatial patterns of clusters of higher levels of disparity (hot spots) and identifies significant environmental factors which contribute to the formation of the hot spots. Data comes from the WBC project covering an urbanized part of King County, Washington, at the individual level. The global spatial autocorrelation level is measured by Moran's I and the local spatial patterns of autocorrelation are described by Local Index of Spatial Association (LISA) maps.

#### 4.2.1. Individual Health Disparity

The average Gini coefficients in health status and BMI were 0.12476 and 0.08691, respectively, while the standard deviation of the Gini coefficient in BMI (0.01608) was greater than in health status (0.01438). Thus, obesity disparity had a wider distribution with a relatively higher mean than the distribution in health status disparity.

Health status and obesity disparities were described in the GIS maps of Figures 4.5 and 4.6, respectively. Most respondents were clustered in the City of Seattle and a few individuals located in the surrounding areas. Obesity disparity had clear geographical clustering patterns while the spatial patterns of health status disparity were unclear. First, respondents with lower obesity disparities were closer to the center of downtown Seattle, whereas respondents with higher obesity disparity were further away from downtown. Second, individuals with lower obesity disparities tended to be located on the coast and individuals with higher obesity disparities tended to agglomerate in the east of the study area. However, it is difficult to diagnose the overall patterns of health disparity using only GIS maps. Therefore, more detailed analyses, such as hot spot analysis and multiple regression models, are employed in the next sections.

The City of Seattle has 13 neighborhood districts which are locally defined administrative boundaries and the perception of individual neighborhoods is relatively strong. Based on the ANOVA test, health status disparity (F-statistic=25.503) and obesity disparity (F-statistic=27.794) are different by the neighborhood district at the .001 significant levels. While there is no strong spatial pattern of health status disparity, the spatial pattern of obesity disparity is distinctive at the neighborhood district level. Based on an ANOVA and post-hot test, the Ballard (Gini coefficient =0.07235), the Southwest (0.07588), and the Northwest (0.07961) are subsets of significantly lower levels of obesity disparity while the Northeast (0.10824) has a higher disparity comparing with the citywide average disparity level, 0.08636.

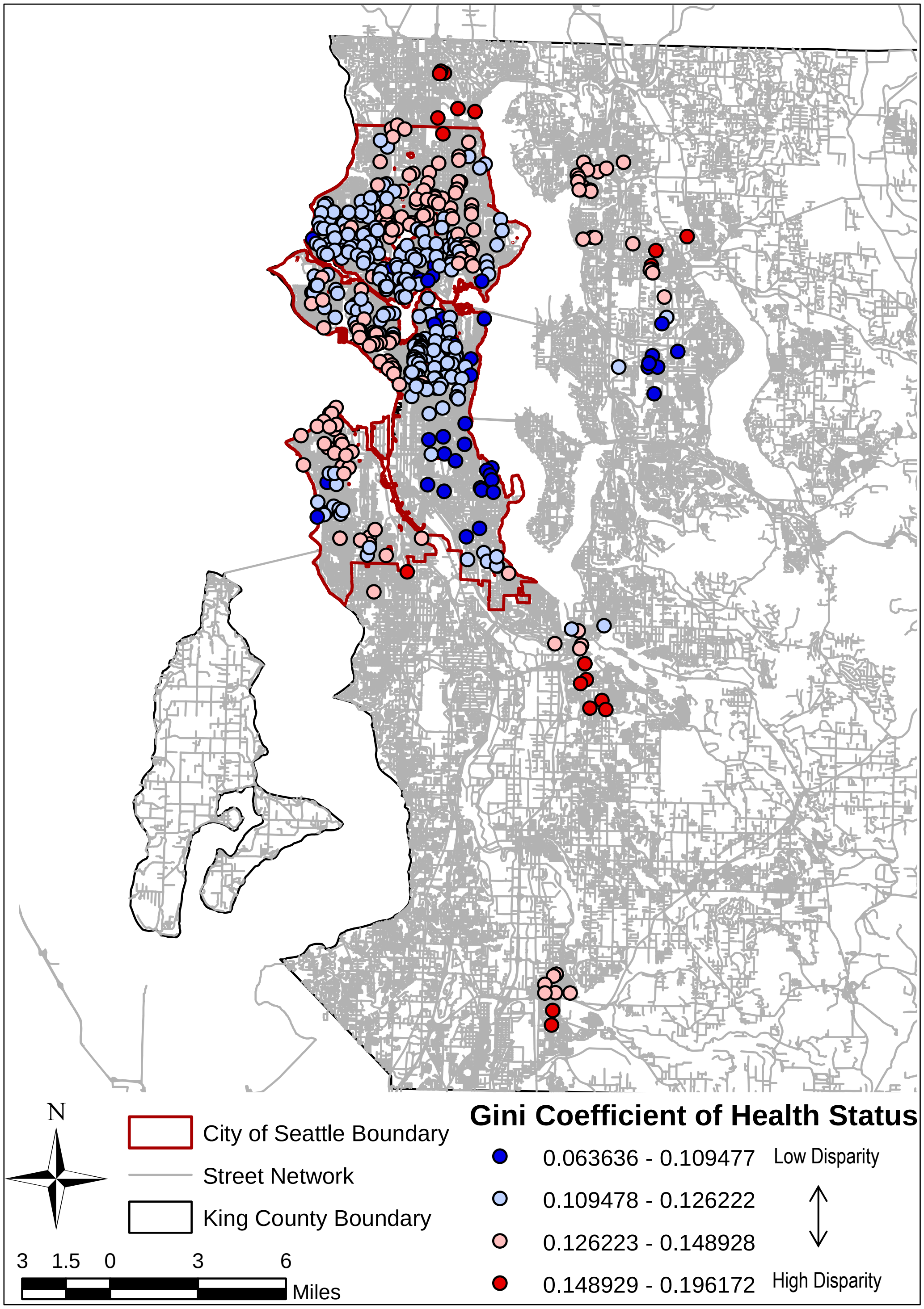


Figure 4.5. Individual Health Status Disparity

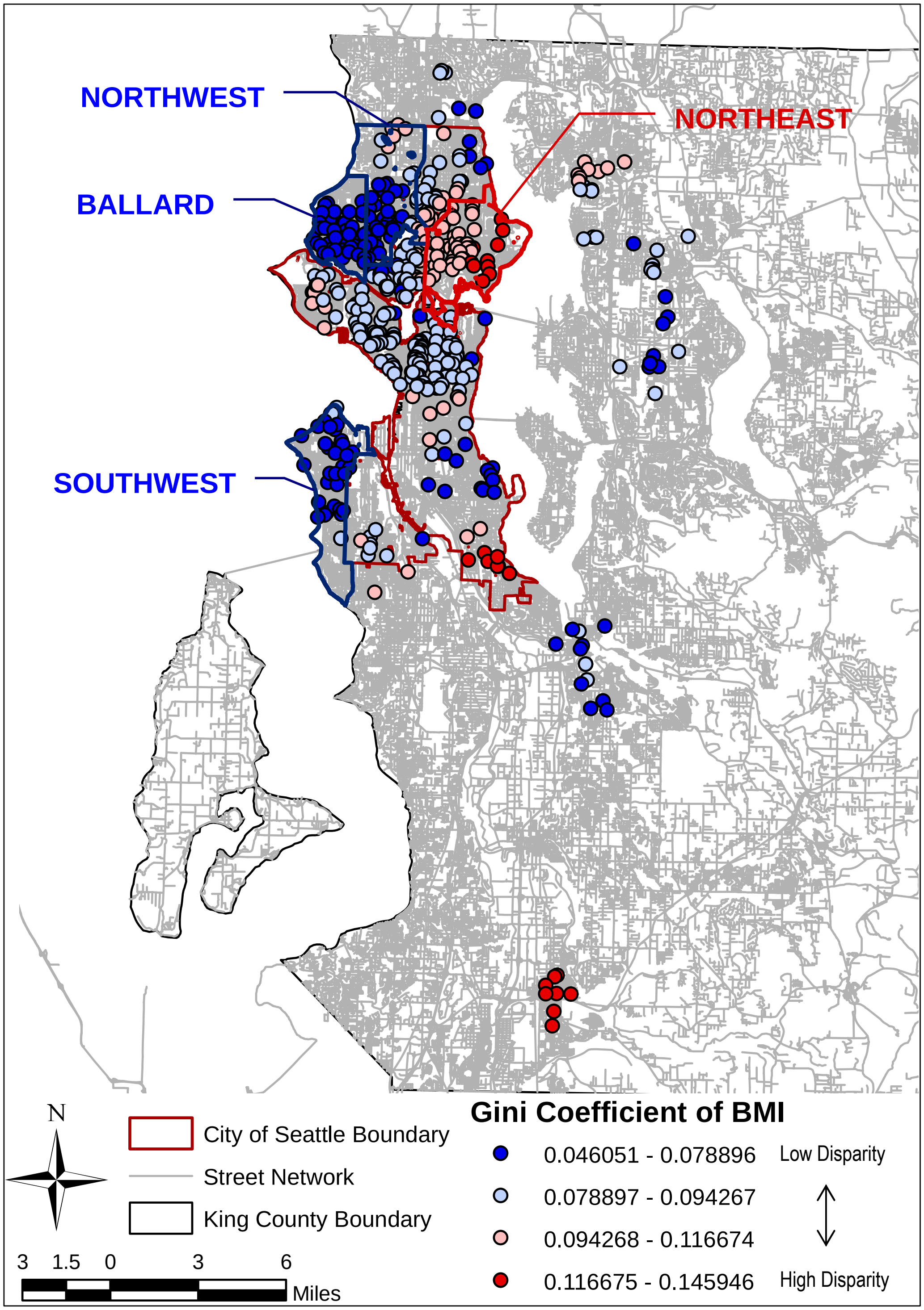


Figure 4.6. Individual Obesity Disparity

All four neighborhood districts with clusters of high and low disparities are above the citywide average for the household income and the percentage of white populations. But the percentage of the population below the poverty level is clearly different between the lower and higher levels of obesity disparities. Three neighborhood districts (e.g. the Ballard, the Southwest, and the Northwest) with lower levels of disparity have very low percentages of people below poverty whereas the Northeast district has an above average percentage. Thus, there is no severe income inequality in the Ballard, the Southwest, and the Northwest, while the Northeast has a high level of disparity in income.

The Ballard and the Northwest neighborhood districts are fairly old, livable, and walkable communities with features supporting physical activity such as medium density, connected streets, and mixed land use. The Southwest district includes newer developments and houses a mixture of newer and older single family units. Household income level ($58,007) is the highest among the 13 neighborhood districts in Seattle and the percentage of the population below the poverty level is 4.7 % - one of the lowest percentages in all the neighborhood districts. In summary, three districts have medium and high levels of income and are below the citywide average for the percentage of the population below the poverty level. All three districts have walkable neighborhood parks and enjoyable commercial facilities including shopping centers, restaurants, and retail stores along the waterfront.

The Northeast consists of two different sub-districts including the University Community and single family residential districts. The southwest part of this district, called the University Community, is where the University of Washington is located and contains student facilities such as university apartments, university complexes, research and educational centers, and commercial establishments. This community is very condensed and diverse in its land uses. There are medium or high income levels for single family residential neighborhoods along the waterfront of Lake Washington. Moreover, there are huge waterfront parks to the east and a golf course to the north. Thus, the Northeast has very different style of communities; one is very dense and diverse in land use with low income residential units and the other is has a medium and high income single family residential area with high property values. The distinctive community differences may cause high levels of health disparity. As a whole, the Northeast is above average for income level, but the percentage of the population below poverty is higher than the citywide average. Thus, the Northeast has greater income disparity in addition to health disparity.

### 4.2.2. Hot Spot Analysis

#### 4.2.2.1. Overall Hot Spot Pattern

Before going into an explanatory analysis investigating the detailed built environmental correlates of health status, obesity, and health disparity, a quick snap shot through hot spot analysis, including spatial autocorrelation test and descriptive statistics, is done. Hot spot analysis, or cluster and outlier analysis, is valuable not only for the preparation of the explanatory analysis and multiple regression model, but also for the exploration of the spatial information itself.

Univariate Moran's Is of health status disparities using the 4-nearest neighbors, 10-nearest neighbors, and 3km distance spatial weights were 0.7602, 0.6459, and 0.6071; obesity disparity's Moran's Is with the 4-nearest neighbors, 10-nearest neighbors, and 3km distance matrices were 0.9286, 0.7523, and 0.7193. See Figures 4.7 through 4.12. All six Moran scatter plots described strong positive slops (0.6071 – 0.9286) and most respondents converged on the fitted lines. They showed that health disparity had a strong positive autocorrelation and obesity disparity was very strongly concentrated in hot and cold spots.

Overall patterns of local spatial autocorrelations in the health status and obesity disparities were similar even if the total numbers of hot spots (high-high, red dots in the LISA maps), cold spots (low-low, blue dots), and outliers (not significant, white dots) were different depending on the methods of spatial weights. There existed local differences in hot and cold spots between health status and obesity disparities. According to the LISA maps in Figures 4.7 through 4.12, hot spots of health status disparity agglomerated closer to the center of downtown Seattle while cold spots were further away from the center. The hot spots of obesity disparity were concentrated in the east side of the study area and the cold spots were located in the west side of the study area. These findings are consistent with the overall patterns of health disparities described with the GIS maps in Figures 4.5 and 4.6.

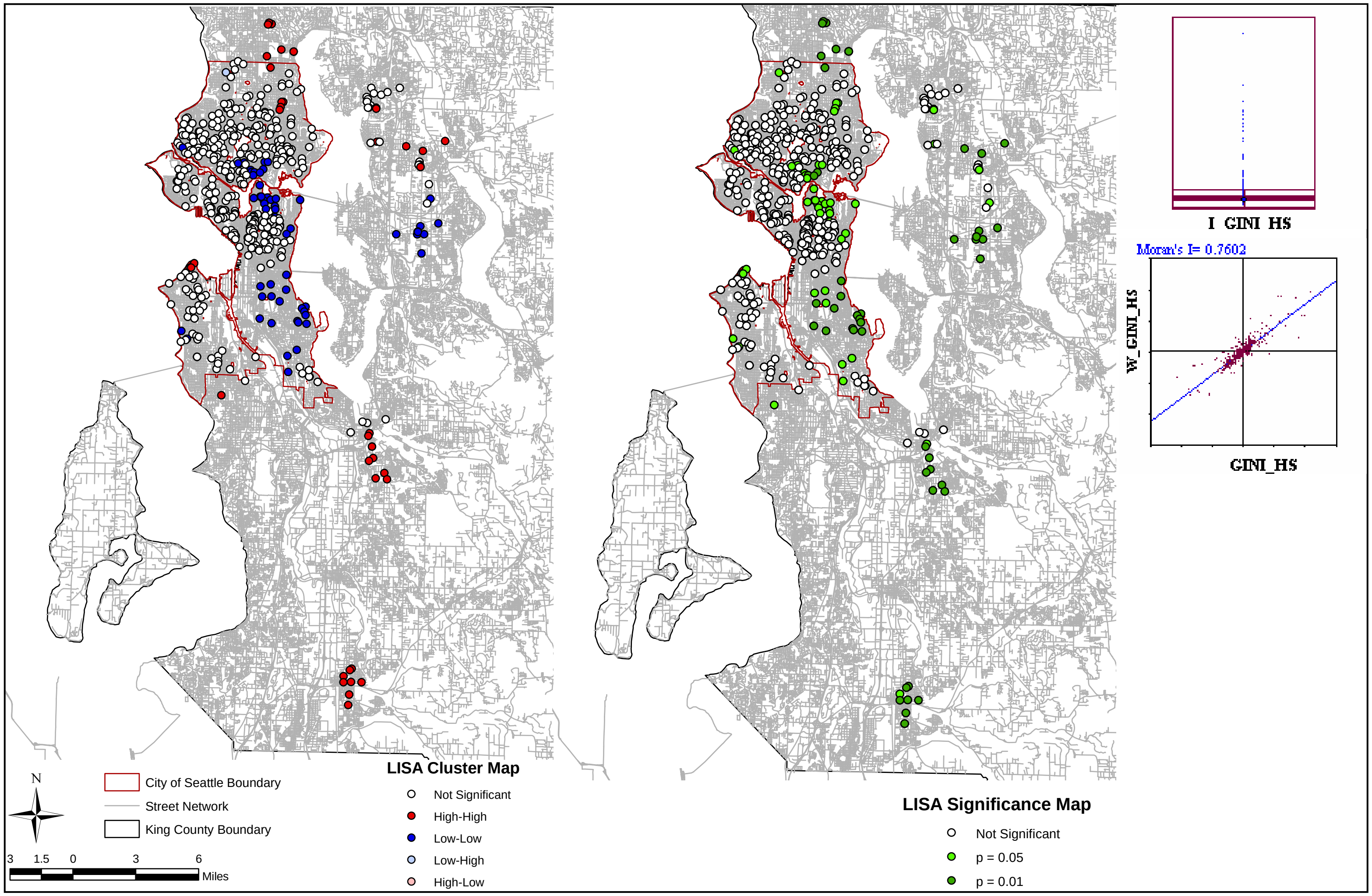


Figure 4.7. LISA Maps and Graphs of Health Status Disparity (Spatial Weight: 4-nearest Neighbors)

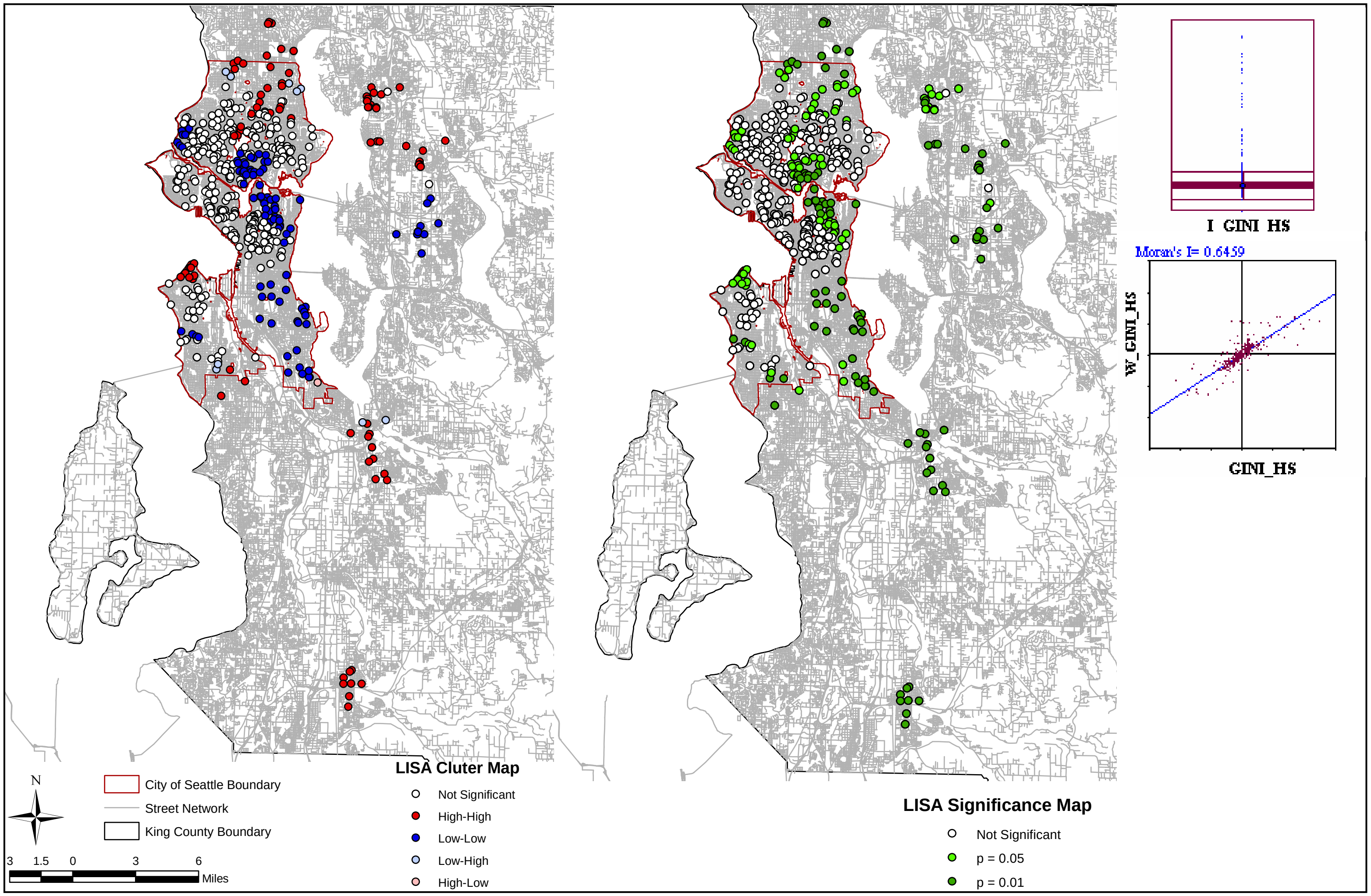


Figure 4.8. LISA Maps and Graphs of Health Status Disparity (Spatial Weight: 10-nearest Neighbors)

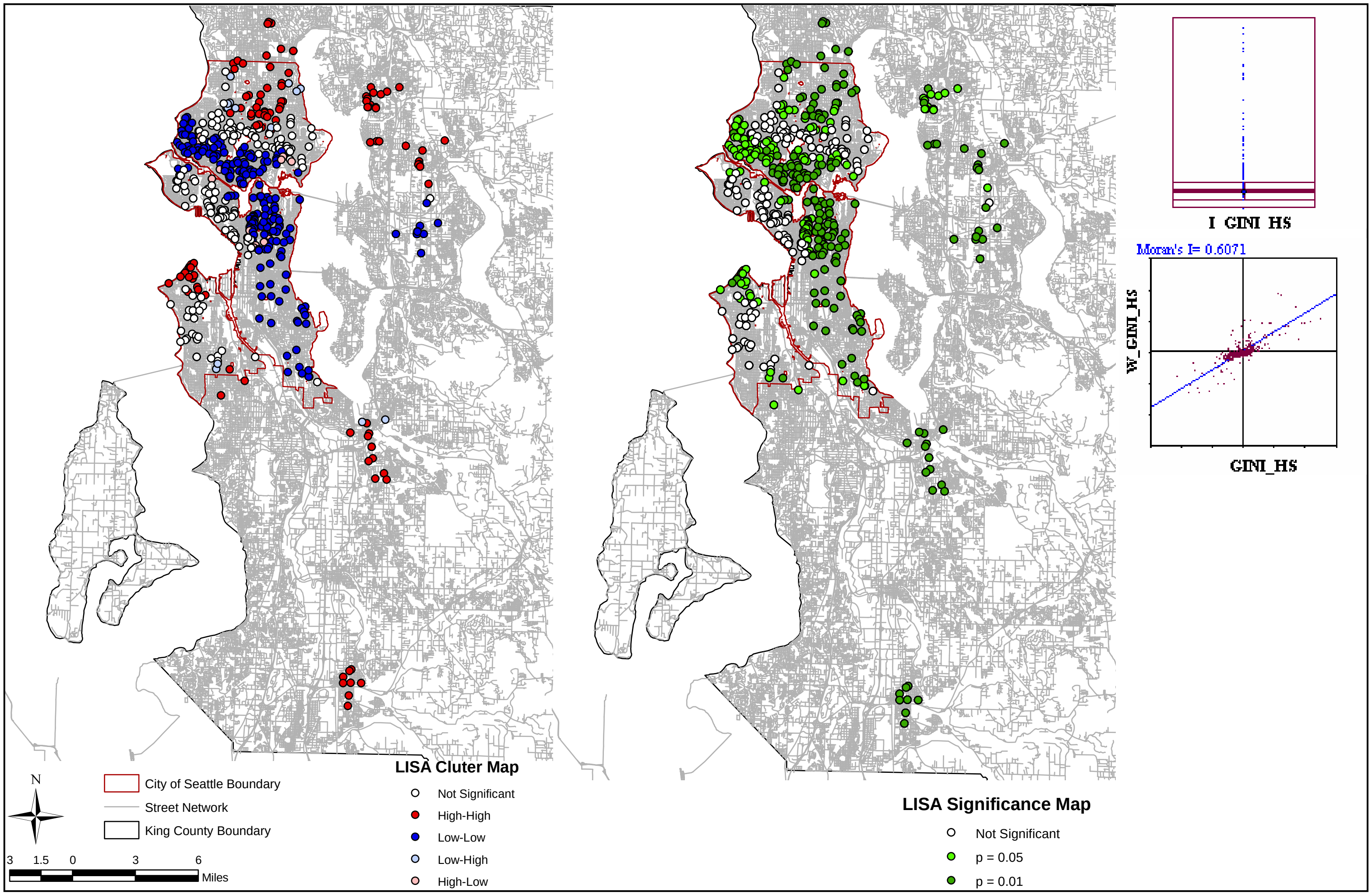


Figure 4.9. LISA Maps and Graphs of Health Status Disparity (Spatial Weight: 3km Distance)

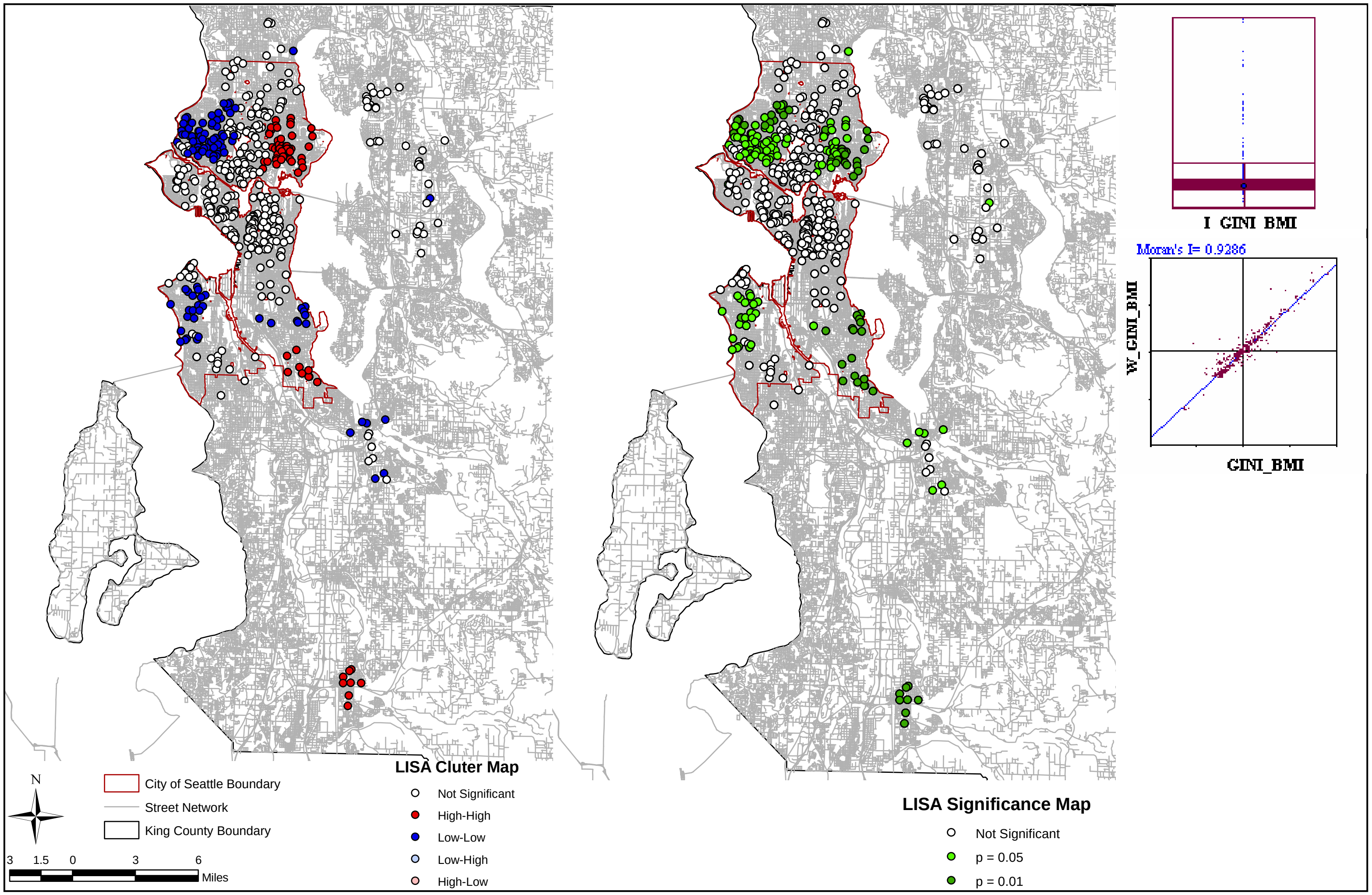


Figure 4.10. LISA Maps and Graphs of Obesity Disparity (Spatial Weight: 4-nearest Neighbors)

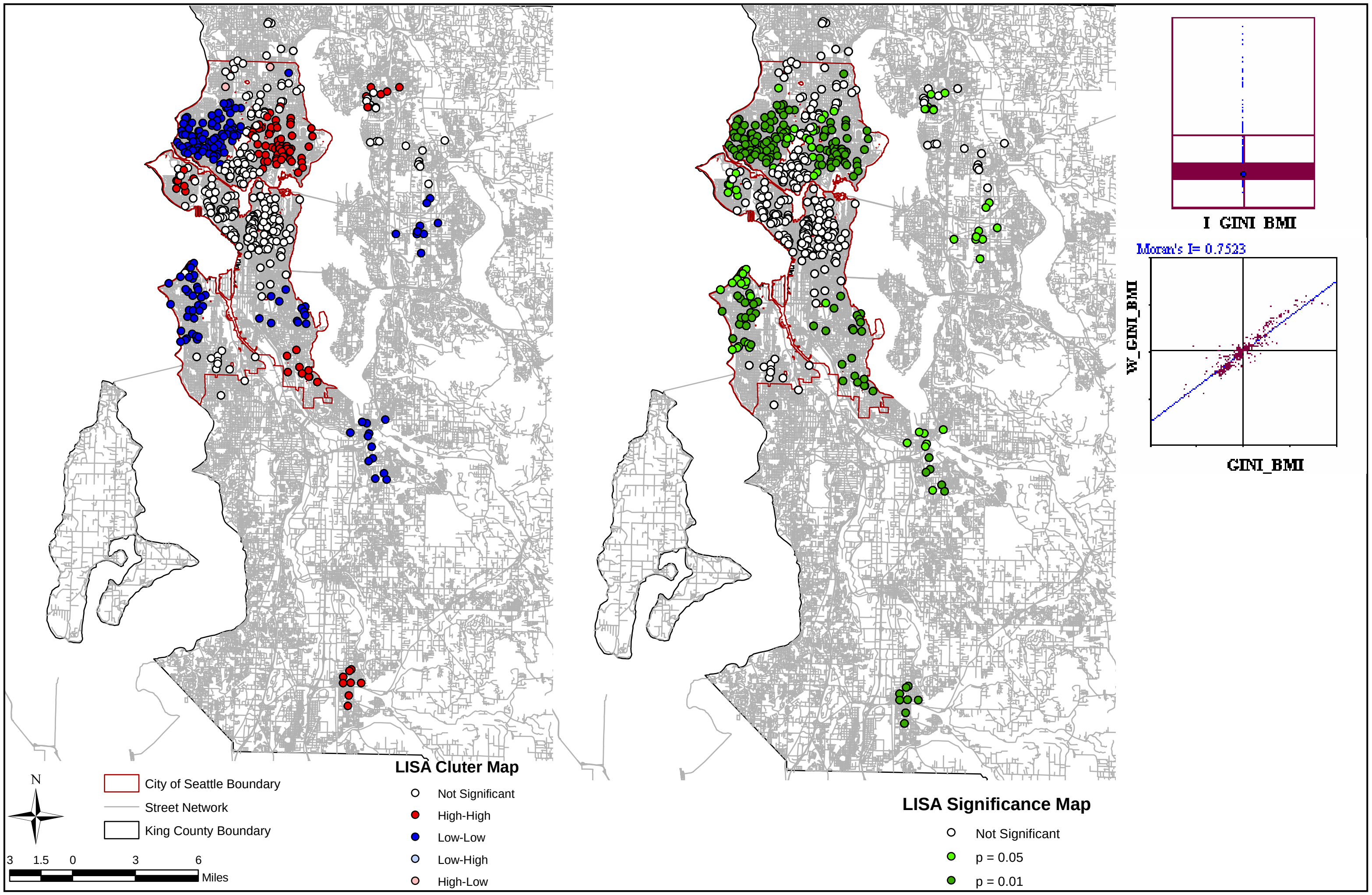


Figure 4.11. LISA Maps and Graphs of Obesity Disparity (Spatial Weight: 10-nearest Neighbors)

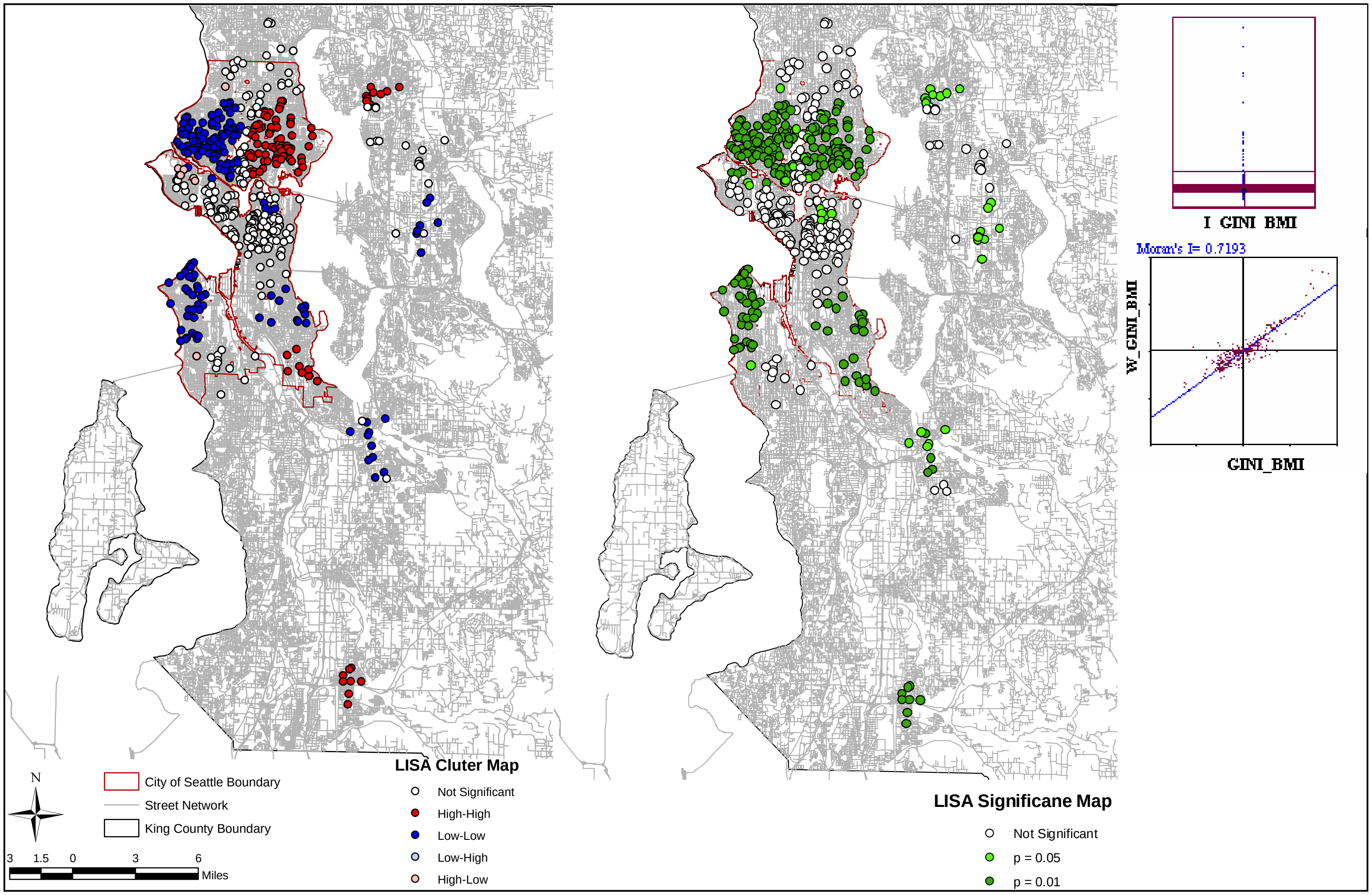


Figure 4.12. LISA Maps and Graphs of Obesity Disparity (Spatial Weight: 3km Distance)

### 4.2.2.2. Built Environmental and Personal Factors Influence on Hot Spots

Are there specific built environmental and personal factors which influence the hot spots in health disparities? This question tests hypothesis one – that hot spots have less supportive built environments than cold spots. In order to determine the significant effects of hot and cold spots in health disparity, the 503 respondents were classified into hot spot (high-high), cold spot (low-low), and outlier (not significant) groups. Note that individuals of negative spatial autocorrelation (low-high or high-low) were lumped into outlier groups because their total numbers were too small to be handled as ordinary groups themselves.

To find factors which were significantly different among the three groups (hot spot, cold spot, and outlier), ANOVA and a post hoc multiple comparisons among the groups were used. Although there were many more relevant factors that affected each hot spot per each weight matrix, only the common significant variables among the three weight matrices were used. Table 4.8 describes the results of ANOVA which present all p-values from the six cases as less than 0.05. Thus, it can be concluded that at least one group among the hot spots, cold spots, and outliers was different from the other two groups with respect to the variables from the ANOVA tables. Further information on descriptive statistics, Levene's and the Kruskal-Wallis tests for assumption checks, ANOVA, and homogeneous subsets is located in Appendix 2.

Several tests were performed to make sure that the data met the assumptions of ANOVA. To verify the homogeneity of variance, Levene's test was used first. Most p-values of the variables used in this study are less than 0.010; this means that the variances of the three groups (hot spots, cold spots, and outliers) would be considered unequal. So the nonparametric Kruskal-Wallis test was employed instead. All p-values, except for education level (0.135, 0.110, and 0.379 using the 4-nearest neighbors, the 10-nearest neighbors, and the 3km distance spatial weights) in obesity disparities were less than 0.05; thus there were no strong inequality of variance and non-normality. It was concluded that the assumptions of ANOVA were attained using the non-parametric test. Descriptive statistics depict the basic and detailed information of each significant variable.

To test the hypothesis that hot spots have less supportive built environments than cold spots, Table 4.8 describes the overall results in the investigation of what factors are more and/or less influential in hot and cold spots. This table tabulates the results of homogeneous subsets based on the 4- and 10-nearest neighborhoods and 3km distance measures. For example, the '+' sign of distance to downtown factor in hot spot means that cluster of hot spots are further from downtown through all three spatial weight measures.

Table 4.8. Signs of Significant Influences of Built Environmental Factors on Hot Spots

| Variable | Measurements | | Health Status Disparity | | Obesity Disparity | |
|---|---|---|---|---|---|---|
| | | | Hot spot | Cold spot | Hot spot | Cold spot |
| Distance to downtown | Distance to Seattle downtown | | + | | + | |
| Destination | Number of each destination within a 1km network buffer | Church | − | | − | |
| | | Grocery store | − | | | |
| | | Mixed use | − | | | |
| | | Museum | | | − | |
| | | Office | | | − | |
| | | Regional shopping center | | | + | |
| | | Retail store | | | − | |
| | | Theater | | | − | |
| | Distance to the closest each destination within a 3km network buffer | Church | + | | | |
| | | Neighborhood/community shopping center | − | | | + |
| | | Grocery store | + | | | |
| | | Library | + | | | |
| | | Museum | + | | + | − |
| | | Regional shopping center | | | − | |
| | | School | + | | | |
| | | Theater | | | + | |
| Street length | Total length of street | | − | | | |
| Sign | Number of traffic signs | | − | | | |
| Sidewalk | Total sidewalk length | | − | | | |
| Intersection | Number of intersections | | − | | | |

Coding and descriptive statistics are available in Tables 3.4 through 3.8.

The overall findings from the hot spot analysis had the following points.

First, as the LISA maps visually described, agglomerations of hot spots were furthest away from downtown Seattle; not only the intuitive maps, but also the quantitative results from the hot spot analysis confirmed this. Areas near downtown Seattle are older with smaller street blocks and higher densities which are shown to support physical activity. This supports the hypothesis that hot spots have less supportive built environments than cold spots. Residents who live in a suburban area are more likely than those who live in downtown to use automobiles instead of walking or biking according to many previous findings. Because one characteristic of the supportive built environments in this study is increases in physical activity such as walking and biking, it is expected that the factor of distance from downtown has positive relationship with the hot spots. Thus, the further from downtown one is, the more hot spots are clustered.

Second, destinations for promoting physical activities were fewer, or further from, the hot spots. The number of churches, mixed use spaces, and offices in the hot spots were fewer than in the cold spot and the outlier groups; the distances to churches and schools were further from the hot spots than in the others. For example, schools and offices bring commuting trips during the day and churches lead extra activities as well. In sum, the built environments which promote physical activities are less present in the hot spots. Again, this confirms that the hypothesis was tested correctly.

Third, public recreation, leisure, cultural facilities, and utilitarian facilities (e.g. museums, retail stores, theaters, and libraries) were significantly correlated with hot and/or cold spots. The number of museums, retail stores, and theaters was fewer in the hot spots; distances to libraries, museums, and theaters were greatest from the hot spots. A notable point is that these destinations can be classified as facilities which increase physical activity. For example, recreational and cultural destinations promote walking, biking trips, and also encourage extra activities. It can be interpreted that people may choose to walk or bike for trips to small-sized retail stores within a neighborhood (utilitarian walking/biking trips). Thus, recreational, cultural, and utilitarian facilities which promote walking and biking were less frequent within the hot spots.

Fourth, big box shopping centers were greater in number and closer to the hot spots, while being further from the cold spots. The numbers of and distance to regional shopping centers were greater and closer, respectively, in the hot spots. Distances to neighborhood or community shopping centers were furthest from the cold spots. The fewer in number or the further away big sized shopping centers were, the more equitable health disparity was. This could be interpreted that large car parking lots near big shopping centers are obstacles for walking. Thus, big shopping centers in the built environment reduce physical activity and intensify health disparity.

Fifth, the findings showed that fewer grocery stores existed in the hot spots or that they were further away. Because grocery stores are considered facilities which promote healthy diets, this finding also fits the hypothesis. Thus, areas with fewer built environments that support healthy diets have more hot spots than areas with more supportive built environments. Interestingly, other food destinations, such as restaurants, fast food chains, and convenience stores didn't significantly relate with hot or cold spots.

Sixth, from the objective measure and infrastructure section there were less positive infrastructure conditions in the hot spots. This included the total lengths of streets and sidewalks, numbers of traffic signs, and intersections. The length of sidewalks was negatively related to hot spots. The longer the sidewalks, the lower health disparity was. It is unclear if the length of streets and the numbers of traffic signs and intersections promotes or reduces physical activity because their relationships with walking are different depending on the road size and neighborhood conditions. For example, the total street length and numbers of traffic signs and intersections indicate an easy access to walking when a neighborhood size is small. Conversely, their roles are interpreted as auto-oriented facilities which reduce walking and biking if there is huge conglomeration of road systems (e.g. highway crossovers). Moreover, there was a strong correlation between street and sidewalk lengths and between the numbers of traffic signs and intersections. To better examine the role of the built environment on health disparity, it is necessary to do a more detailed analysis (such as a correlation test or multiple regression model). Nevertheless, it’s clear that there was insufficient infrastructure in the hot spots.

Lastly, hot spots had lower education levels and household incomes while cold spots had higher household incomes from the demographic characteristics. Only education and household income levels significantly affected the hot and the cold spots; other factors such as age, gender, and ethnicity had no effect.

### 4.2.3 Conclusion

As an exploratory analysis, it is worth identifying where intensive autocorrelations exist, what the spatial configuration is, and which built environmental factors influence hot spots in health disparity. In brief, the key findings and results of the exploratory study of aim two have important points as follows.

There is a strong neighborhood pattern of obesity disparity in Seattle. Respondents with higher obesity disparities are crowded in the Ballard, the Southwest, and the Northwest, and individuals with lower disparities are located in the Northeast neighborhood district. A notable point is that there are clearly neighborhood differences between them. The Ballard, the Southwest, and the Northwest have low levels of income disparity while the Northeast shows high income disparity, diverse land use, and high density.

Strong spatial autocorrelations (Moran's I: 0.6071 – 0.9286) were found for health disparities, indicating that their levels are not distributed equally across different geographic areas.

Significant factors which influenced the hot spots were different between health status and obesity disparity. Only hot spots in health status disparity were affected by the built environment and personal variables; there were no significant factors that affected the cold spots. There were several factors which influenced both hot and cold spots in obesity disparities. Moreover, the types of significant factors were different between health status and obesity disparities; though there were common factors which influenced both disparities (e.g. distance to downtown, number of churches, and distances to neighborhood/community shopping centers and museums) most influencing factors were dissimilar to each other. Thus, depending on the type of health disparity indicator, the significant factors which influence each disparity were still different.

Areas with supportive built environmental conditions were less likely to be associated with hot spots. Variables which correlated significantly with high disparity hot spots included the proximity to downtown and access to various destinations such as offices, schools, churches, grocery stores, museums, theaters, libraries, and large shopping centers. These hot spots had poorer transportation infrastructure than the cold spots (areas with lower health disparity). According to the hypothesis, infrastructure which promotes physical activity would be negatively correlated to health disparity. However, it is unclear if classifying the employed variables into supportive and adverse impacts on physical activity depends on the types of infrastructure and neighborhood conditions; there were strong correlations among the variables used and a more detailed study including multivariate analysis is required in order to better understand the relationship.

The overall results from this spatial investigation showed that the built environment, when compared to personal factors, had a stronger contribution to the spatial clustering of high health disparity. While there are 21 significant built environmental factors, the significant personal factors only included education level and household income. This result provides a motivation for the main analysis to exam the relationship between the built environment and health disparity.

## 4.3. Aim Three

Aim three is to address the relationship between the built environment and health status, obesity, and health disparity at zip code (Section 4.3.1) and individual (Section 4.3.2) levels. The data come from the WBC subject covering urbanized part of King County, Washington. The bivariate correlation analysis at the zip code level and the multiple regression model at the individual level are used to identify the built environmental correlates of health status, obesity, and health disparity.

### 4.3.1. Zip Code Level Analysis

According to the results of correlation test from Section 4.1, socio-demographic factors appear to be related to health disparity. Although the literature has confirmed that demographic factors influence health, it has remained unclear whether the environment, especially the built environment, is associated with health disparity and which of its specific attributes are most influential. This section of the dissertation research used bivariate correlation analysis to identify the environmental correlates of health disparity. The unit of analysis is the zip code area. Measures from individual respondents are aggregated up to the zip code level and the mean value of each zip code area is used for the analysis.

This analysis focuses on a small number of variables due to the small number of samples (degrees of freedom) available at the zip code level. But a convenient and informative approach with clear spatial boundaries for analysis is needed to bridge the findings and results to policy implementations. The strength of this step of analysis is to examine the built environment-health disparity relationship at an administrative boundary for appropriate, easy to apply policies.

#### 4.3.1.1. Spatial Patterns of Health Disparity at the Zip Code Level

The WBC survey partially or fully covered 50 zip codes in King County, Washington. Only 25 zip codes were included in the health disparity in the analysis based on having at least 10 respondents within each zip code area. There is no clear recommendation on how many is needed to compute the Gini coefficient, but 10 is usually considered acceptable.

The means of Gini coefficients in health status and BMI at the zip code level were 0.12870 and 0.08745, with the standards deviations of 0.02734 and 0.01898, respectively. Overall, zip codes further away from downtown had higher disparities in both health status and obesity (Figure 4.13).

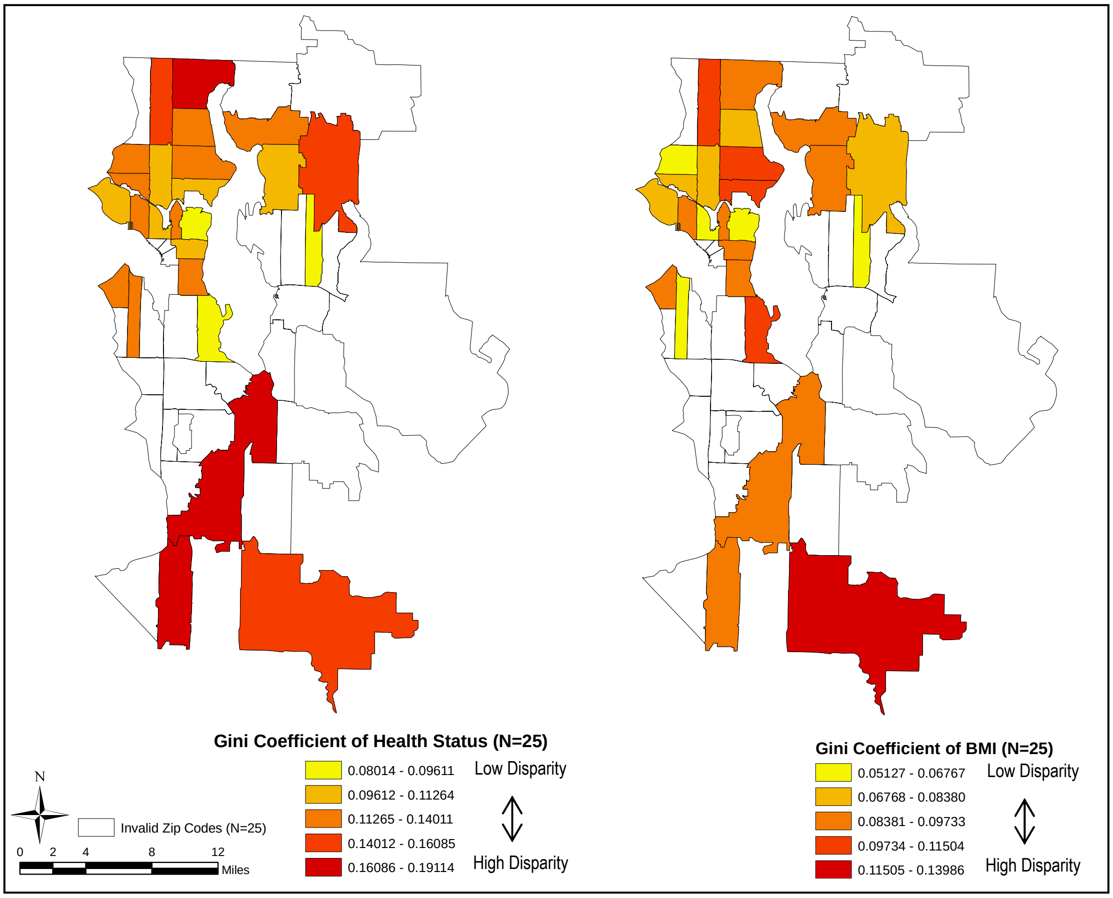


Figure 4.13. Health Status and Obesity Disparity at the Zip Code Level

### 4.3.1.2. Built Environmental and Personal Correlates of Health Status and Obesity at the Zip Code Level

This examines the relationships between the built environmental and personal variables, and health status and obesity at the zip code level. Variables are selected from Tables 3.4 through 3.8 that may be strongly associated with health status, obesity, and health disparity based on the previous literature. Table 4.9 shows the result of a bivariate correlation test which includes variables significantly related to health status and obesity, and theoretically important variables such as demographics and individual characteristics.

Health status was positively correlated with the total weekly minutes of walking, walking for commuting and to retail services, and transit user, while it had significant negative relationships with the number cars per household and age at the 0.05 level of significance.

On the other hand, obesity was positively related to the distance to downtown, the numbers of utilitarian facilities including banks and day care centers, big box shopping centers such as big box retails, neighborhood/ community shopping centers, and regional shopping centers, and food destinations such as convenience stores, fast food restaurants, and neighborhood centers used for convenience stores, fast food restaurants, and groceries. It also had positive correlations with total street length, traffic speed, and the number of traffic signs. Variables having negative relationships with obesity were the numbers of grocery stores, mixed use spaces, and neighborhood centers used for offices and mixed use. They also included the neighborhood perceptions of the presence of amenities for biking and jogging and the social support for walking and biking, personal walking variables such as the total weekly minutes of walking, the walking for commuting and to retail services, transit users, the preference for walking and biking to solve congestion, total weekly minutes of moderate activity, and demographic variables including gender and race.

Table 4.9. Correlation Test with Health Status and Obesity at the Zip Code Level (N=25)

| Variable | Measurements | | Coding and Descriptive Statistics: Health Status | Coding and Descriptive Statistics: Obesity (BMI) |
|---|---|---|---|---|
| Distance to Downtown | Distance to Seattle downtown | | -.308 | .634(**) |
| Destination | Number of each destination within a 1km network buffer | Bank | -.139 | .583(**) |
| | | Big box retail | -.174 | .501(*) |
| | | Neighborhood/Community shopping center | -.204 | .854(**) |
| | | Convenience store | -.195 | .561(**) |
| | | Day care center | -.195 | .570(**) |
| | | Fast food restaurant | -.176 | .507(**) |
| | | Grocery store | .079 | -.438(*) |
| | | Mixed use | -.068 | -.605(**) |
| | | Regional shopping center | -.047 | .432(*) |
| | Number of each neighborhood center (NC) within a1km network buffer | NC used for offices and mixed uses | -.011 | -.697(**) |
| | | NC used for convenience stores, fast food restaurants, and grocery stores | -.099 | .418(*) |
| Street Length | Total length of street | | -.377 | .554(**) |
| Traffic Speed | Posted traffic speed | | -.096 | .514(**) |
| Sign | Number of traffic signs | | -.035 | .426(*) |
| Neighborhood Perception | Neighborhood perception | Presence of amenities for biking and jogging | .381 | -.472(*) |
| | | Social support for walking and biking in the neighborhood | .048 | -.463(*) |
| Waking minutes | Total weekly minutes of walking | | .400(*) | -.588(**) |
| Transportation Walk | Walk for commuting and to retail services | | .471(*) | -.749(**) |
| Transit Use | Transit User | | .634(**) | -.543(**) |
| Attitude toward Environment/ Transportation | Attitude toward the environment and transportation | Preference for walking and biking to solve congestion | .245 | -.719(**) |
| Moderate Activity | Total weekly minutes of moderate activity | | -.146 | -.534(**) |
| Car Ownership | Number of cars per household | | -.687(**) | -.093 |
| Age | Age | | -.413(*) | -.371 |
| Gender | Female | | -.160 | -.437(*) |
| Race | White | | .086 | -.210 |
| Education | Phase of education | | .259 | -.425(*) |
| Income | Average yearly household income | | .079 | -.280 |
| VMT | Vehicle miles traveled | | -.129 | .223 |
| Sedentary life | Total weekly hours of sedentary life at home | | .189 | .281 |
| Eating Out | Number of eating outs per week | | .376 | -.006 |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Values are Pearson Correlation R.
Coding and descriptive statistics are available in Tables 3.4 through 3.8.

### 4.3.1.3. Built Environmental and Personal Correlates of Health Disparity at the Zip Code Level

Table 4.10 showed that health status disparity was positively correlated with the distance to downtown; the numbers of utilitarian destinations including banks, day care centers, post offices, and theaters; neighborhood/community shopping centers; and food destinations including convenience stores, fast food restaurants, and two types of neighborhood centers used for convenience stores, restaurants, fast food restaurants, and grocery stores. It also had positive relationships with transportation infrastructure such as street length, traffic speed, and the numbers of traffic signs and intersections; as well as the percentage of white populations. Health status disparity had negative associations with the neighborhood centers used for sports facilities and schools, neighborhood perception of social support for walking and biking, walking for recreation and commuting, and education level.

Obesity disparity had positive relationships with the distance to downtown; the number of neighborhood centers used for convenience stores, restaurants, and grocery stores; and transportation infrastructure including street length, traffic speed, and the number of intersections. It was negatively associated with demographic variables such as education and income levels.

Table 4.10. Correlation Test with Health Disparity at the Zip Code Level (N=25)

| Variable | Measurements | | Coding and Descriptive Statistics: Health Status Disparity | Coding and Descriptive Statistics: Obesity Disparity |
|---|---|---|---|---|
| Distance to Downtown | Distance to Seattle downtown | | .650(**) | .480(*) |
| Destination | Number of each destination within 1km network buffer | Bank | .614(**) | .370 |
| | | Neighborhood/Community shopping center | .529(**) | .143 |
| | | Convenience store | .575(**) | .235 |
| | | Day care center | .400(*) | .370 |
| | | Fast food restaurant | .641(**) | .264 |
| | | Post office | .458(*) | .031 |
| | | Theater | .403(*) | .242 |
| | Number of each neighborhood center (NC) within 1km network buffer | NC used for convenience stores, restaurants, and grocery stores | .619(**) | .482(*) |
| | | NC used for sports facilities and schools | -.508(**) | .067 |
| | | NC used for convenience stores, fast food restaurants, and grocery stores | .613(**) | .339 |
| Street Length | Total length of street | | .687(**) | .516(**) |
| Traffic Speed | Posted traffic speed | | .710(**) | .442(*) |
| Sign | Number of traffic signs | | .488(*) | .209 |
| Intersection | Number of intersections | | .564(**) | .555(**) |
| Neighborhood Perception | Neighborhood perception | Social support for walking and biking in the neighborhood | -.592(**) | -.010 |
| Recreation Walk | Walk for recreation | | -.458(*) | -.076 |
| Transportation Walk | Walk for commuting and to retail services | | -.540(**) | -.004 |
| Age | Age | | -.066 | .157 |
| Gender | Female | | -.078 | -.197 |
| Race | White | | .501(*) | -.041 |
| Education | Phase of education | | -.591(**) | -.465(*) |
| Income | Average yearly household income | | -.354 | -.639(**) |
| VMT | Vehicle miles traveled | | .147 | -.083 |
| Sedentary life | Total weekly hours of sedentary life at home | | .022 | -.071 |
| Eating Out | Number of eating outs per week | | .106 | -.013 |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Values are Pearson Correlation R.
Coding and descriptive statistics are available in Tables 3.4 through 3.8.

The correlation of the built environmental and personal factors with health status, obesity, and health disparity are summarized and interpreted as follows. First, supportive built environments that promote physical activity and healthy diets were positively correlated with health status, and negatively related with obesity and health disparity. Supportive built environment features included easy access to destinations such as mixed use spaces and neighborhood centers used for offices, mixed uses, sports facilities and schools; neighborhood perceptions of the presence of amenities for biking and jogging; and social support for walking and biking. Less supportive built environments included accesses to utilitarian facilities, big box shopping centers, and unhealthy food environments. These findings are interpreted as follows. More offices, mixed uses, schools, and sports facilities tended to promote walking, biking, and physical activity. Possibly because proximately located offices, schools, and high mixed uses produce commuting and other various trips, these destinations are negatively related to obesity. Neighborhood perceptions of the presence of amenities and social support for walking, biking, and jogging encourage physical activity including waking and biking and therefore are a barometer for supportive environments. Depending on the facilities and the neighborhood types, the roles of destinations can be different. Utilitarian facilities such as banks and day care centers were negatively related to walking and increased obesity in this study. Big box shopping centers would be considered potentially positive facilities for obesity because the big parking lots near the shopping centers may decrease walkability and this study further confirmed this. Moreover, unhealthy food environments, such as fast food restaurants and convenience stores, can increase the obesity rate.

Second, distance to downtown had positive associations with obesity and health disparity. This finding is consistent with the previous result of the hot spot analysis. It can be interpreted that areas near downtown Seattle support physical activity because it has smaller street blocks and higher density.

Third, obesity and health disparity had positive associations with transportation infrastructure such as street length, traffic speed, and the number of traffic signs and intersections. It may be interpreted that the greater the street length, traffic speed, traffic signs, and intersections, the more cars in the neighborhood and therefore less walking and biking, which ultimately results in increased obesity.

Fourth, health status had positive relationships, and obesity and health disparity had negative relationships, with personal characteristics of waking, use of transit service, favorable attitudes toward environment/transportation, and physical activity. Walking variables included the total weekly minutes of walking, and walking for recreation and commuting. Transit usage was the percentage of transit users, and the attitudes toward the environment and transportation included the preference for walking and biking to solve congestion. The physical activity variable was the total weekly minutes of moderate activity. This was expected in accordance with the findings of previous studies and literature.

Fifth, there were clear relationships between demographic variables and health status, obesity, and health disparity. Age was negatively related with health status, the percentage of female populations had negative association with obesity, and the percentage of white populations had a positive relationship with disparity. Education level was negatively related to obesity and health disparity, and income level had a negative association with health disparity. This was clearly expected from the previous literature.

#### 4.3.1.4. Conclusion

It appears that health disparity is significantly associated not only with demographic and economic factors, but also with built environmental factors. This study brings attention to the problem of health disparity in the US, and adds to the previous literature on health and obesity by focusing on the levels of disparity at the zip code level. The findings suggest the potential roles that the built environment plays in increasing or decreasing health disparity beyond the traditional income and demographic factors.

This analysis was limited to the small sample size of 25 zip code areas, but it provides a basis for more detailed and extensive studies to better understand the environmental and socioeconomic conditions associated with health disparity, and to develop policy recommendations to help reduce it in the US from the urban/transportation planning and public health perspectives. More detailed analysis (e.g. multivariate analysis at the individual level) will be dealt with in next section.

### 4.3.2. Individual Level Analysis

Based on the results in Section 4.3.1, the built environment is associated with health status, obesity, and health disparity at the zip code level. While the findings at the zip code level offer aggregated, bivariate, and therefore somewhat crude information on the environment-disparity issues, its boundaries are spatially clear and therefore make it easy to translate into interventions or policy recommendations. To identify more detailed information about the roles of the built environment on health status, obesity, and health disparity, this phase of analysis executes an individual level of analysis using multivariate analysis. The individual level of study will theoretically bring more detailed and disaggregated results. According to the results of the hot spot analysis from Section 4.2, there were strong spatial autocorrelations (Moran's I: 0.6071 – 0.9286) in health disparity. Because of the strong spatial dependence in health disparity, a spatial regression model is used instead of an OLS regression model.

The analysis process follows the basic steps used for the zip code level analysis. The unit of analysis is the individual. The objective variables come from the GIS measures taken from the 1km (all number measures of destinations) and the 3km (all distance measure of destinations, land use, and infrastructure data) buffers from each respondent, and all subjective variables come from the survey.

#### 4.3.2.1. Health Status and Obesity Condition at the Individual Level

***(a) Correlation Test with the Selected Variables (Steps 1 & 2)***

Table 4.11 describes the built environmental and personal variables selecting from Tables 3.4 through 3.8 that strongly related to health outcomes, physical activities, and food environments based on the previous literature and the findings of bivariate correlation analysis at state and zip code level from the previous chapters. The developed conceptual framework suggests that built environmental factors related to physical activity and dietary patterns are correlated with health status, obesity, and even health disparity. Not only the built environment, but also the socio-demographic variables are key contributors to many public health challenges such as obesity, diabetes, cardiovascular disease, and depression. Thus, to better capture the built environmental and socio-demographic influences on health status and obesity, this study should capture all relevant constructs/categories. The list includes health care, food-related, and physical activity-related destinations, walking-related and physical activity-related personal factors, and demographics as sub-categories.

For the built environmental factors, the health care destination category was captured by the number of and the distance to hospitals. Food-related and physical activity-related destinations included the numbers of and the distance to grocery stores, fast food restaurants, bars, convenience stores, and restaurants, and the number of and the distance to parks, and lengths of regional trails, respectively. For the personal variables, the walking category included the total weekly minutes of walking and variables of recreation, commuting, and to retail services. The physical activity category covered the level of physical activity at work, and the total weekly minutes of vigorous and moderate activity. Age, gender, the percentage of white population, education level, and yearly household income were used as demographic factors.

Table 4.11. Correlation Test with Health Status and Obesity

| Variable | Measurements | Health Status | Obesity (BMI) |
|---|---|---|---|
| Health Care Destination | Number of hospitals | -.018 | .030 |
| | Distance to hospital | -.008 | .023 |
| Food-related Destination | Number of grocery stores | -.041 | -.050 |
| | Number of fast food restaurants | -.063 | .036 |
| | Number of bars | -.036 | .023 |
| | Number of convenience stores | -.053 | .017 |
| | Number of restaurants | -.049 | -.017 |
| | Distance to grocery store | .047 | .045 |
| | Distance to fast food restaurant | .060 | -.031 |
| | Distance to bar/tavern | .022 | -.021 |
| | Distance to convenience store | .060 | .011 |
| | Distance to restaurant | -.040 | .029 |
| Physical Activity-related Destination | Number of parks | .081 | .025 |
| | Length of regional trail | -.030 | -.016 |
| | Distance to park | -.078 | .016 |
| | Distance to regional trail | .036 | -.036 |
| Walking-related Personal Factor | Total weekly minutes of walking | .091(*) | -.139(**) |
| | Walk for recreation | .059 | -.038 |
| | Walk for commuting and to retail services | .017 | -.109(*) |
| Physical Activity-related Personal Factor | Phase of physical activity at work | .107(*) | -.004 |
| | Total weekly minutes of vigorous activity | .195(**) | -.105(*) |
| | Total weekly minutes of moderate activity | .076 | -.081 |
| Demographics | Age | .011 | .112(*) |
| | Gender (Female) | .088(*) | -.129(**) |
| | Race (White) | .084 | .048 |
| | Education | .205(**) | -.125(**) |
| | Income | .162(**) | -.118(**) |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Values are Pearson Correlation R
Coding and descriptive statistics are available in Tables 3.4 through 3.8.

Six and seven variables (out of the total of 27selected variables) were significantly correlated with health status and obesity, respectively. They were all personal factors and included the total weekly minutes of walking, walking for commuting and to retail services, phases of physical activity at work, total weekly minutes of vigorous activity, age, gender, education, and income. None of the built environmental variables were significantly correlated with health status and obesity.

***(b) Correlation Test at the Category Level (Step 3)***

As shown in Table 4.12, there were correlations between the total weekly minutes of walking and walking for commuting and to retail service, phases of physical activity at work and total weekly minutes of vigorous activity, and education level and annual household income.

Table 4.12. Categorical Correlation Test for Health Status and Obesity Models

| Variable | Measurements | Walk for commuting and to retail services | Total weekly minutes of vigorous activity | Gender (Female) | Education | Income |
|---|---|---|---|---|---|---|
| Walking-related Personal Factor | Total weekly minutes of walking | .332** | | | | |
| Physical Activity-related Personal Factor | Phase of physical activity at work | | .118** | | | |
| Demographics | Age | | | .156** | -.085 | -.079 |
| | Gender (Female) | | | | -.015 | .012 |
| | Education | | | | | .364** |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Coding and descriptive statistics are available in Tables 3.4 through 3.8.

To avoid strong collinearities among the variables in the regression analysis, one variable per category needed to be selected for the preliminary regression models. In short, according to both correlation analyses described in Tables 4.11 and 4.12, the health status regression model would include the total weekly minutes of walking, gender, one variable from either the phases of physical activity at work or total weekly minutes of vigorous activity, and one from education level or income; the regression models measuring obesity contained the total weekly minutes of vigorous physical activity, and one variable each from either of the following pairs: the total weekly minutes of walking or walking for commuting and to retail services, age or gender, and education level or annual household income.

***(c) Preliminary Model (Steps 4 & 5)***

The distribution of the 5-point Likert scale perceived health measure was non-normal. The numbers of respondents who rated their perceived health as poor, fair, good, very good, and excellent were 4 (0.8%), 33 (6.6%), 134 (26.6%), 201 (40.0%), and 131 (26.0%), respectively, out of total of 503 (100%). The 5-point Likert scales in health status were condensed into two groups. Note that ‘poor’ and ‘fair’ were lumped together with ‘good’, and ‘very good’ was combined with ‘excellent’. Thus, the numbers of respondents of ‘good’ and ‘excellent’ statuses in health became 171 (34.0%) and 332 (66.0%), respectively. Because of this dichotomous independent variable, a binary logistic regression model was employed in estimating health status. Meanwhile, an OLS regression model was used to estimate obesity because it is a continuous variable.

As the measures Nagelkerke R square and adjusted R square indicate, each model captured 19.2% and 15.8% of evidences of good fit. Moreover, the classification accuracy rate was 70.4% which was greater than the proportional by chance accuracy criteria of 68.9% needed to satisfy the use of the binary logistic regression model in health status. The Durbin-Watson statistic (2.005) was close to 2, which suggests the presence of small residual autocorrelation for the obesity model.

Table 4.13. Built Environmental and Personal Correlates of Health Status (Preliminary Model)

| Variable | Measurements | | B* | S.E. | Wald | df | Sig. | Exp(B) | 95.0% C.I. for EXP(B) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Lower | Upper |
| | Constant | | 4.999 | 3.738 | 1.788 | 1 | .181 | 148.294 | | |
| Obesity | Body mass index | | -.084 | .024 | 12.372 | 1 | .000 | .920 | .878 | .964 |
| Destination | Number of each destination within a 1km network buffer | Grocery stores | -.119 | .058 | 4.197 | 1 | .041 | .887 | .792 | .995 |
| | | Post offices | -.513 | .250 | 4.192 | 1 | .041 | .599 | .367 | .978 |
| | | Parks | .152 | .075 | 4.129 | 1 | .042 | 1.164 | 1.005 | 1.347 |
| Street width | Average number of lanes per way on the street | | .872 | .460 | 3.594 | 1 | .058 | 2.393 | .971 | 5.896 |
| Traffic speed | Posted traffic speed | | -.110 | .057 | 3.715 | 1 | .054 | .896 | .802 | 1.002 |
| Neighborhood perception | Social support for walking & biking in the neighborhood | | .219 | .104 | 4.429 | 1 | .035 | 1.244 | 1.015 | 1.525 |
| Walking minutes | Total weekly minutes of walking | | .039 | .083 | .219 | 1 | .640 | 1.040 | .883 | 1.224 |
| Vigorous activity | Total weekly minutes of vigorous activity | | .399 | .127 | 9.864 | 1 | .002 | 1.491 | 1.162 | 1.913 |
| Gender | Female | | .324 | .209 | 2.406 | 1 | .121 | 1.382 | .918 | 2.081 |
| Education | Phase of education | | .331 | .107 | 9.483 | 1 | .002 | 1.392 | 1.128 | 1.718 |
| Sedentary life | Total weekly minutes of sedentary life at home | | -.242 | .130 | 3.472 | 1 | .062 | .785 | .608 | 1.013 |

* B: coefficient
Coding and descriptive statistics are available in Tables 3.4 through 3.8.

From the Table 4.13, all variables, except for the total weekly minutes of walking (p-value= .640) and gender (p-value= .121), were significant in this preliminary model. Multicollinearity in the logistic regression was detected by examining the standard errors (>2.0) for the coefficients (B). Note that the check for a standard error larger than 2.0

does not include the standard error for the constant. There was no multicollinearity because all the variables had a standard error value of less than 2.0. Thus, the final model was established through the removal of insignificant variables.

Table 4.14. Built Environmental and Personal Correlates of Obesity (Preliminary Model)

| Variable | Measurements | | Unstandardized Coefficients B | Unstandardized Coefficients Std. Error | Standardized Coef. Beta | t | Sig. | Collinearity Statistics Tolerance | Collinearity Statistics VIF |
|---|---|---|---|---|---|---|---|---|---|
| | Constant | | 41.408 | 6.115 | | 6.771 | .000 | | |
| Health Status | Perceived health status | | -1.146 | .209 | -.236 | -5.492 | .000 | .906 | 1.104 |
| Destination | Number of each destination within a 1km network buffer | Churches | -.383 | .149 | -.134 | -2.567 | .011 | .612 | 1.635 |
| | | Fast food restaurants | .274 | .157 | .082 | 1.743 | .082 | .749 | 1.335 |
| | | Mixed uses | -.967 | .283 | -.167 | -3.417 | .001 | .700 | 1.429 |
| | | Museums | 1.033 | .474 | .102 | 2.179 | .030 | .768 | 1.303 |
| Street width | Average number of lanes per way on the street | | -1.861 | .737 | -.124 | -2.526 | .012 | .695 | 1.440 |
| Bus service | Number of bus stops | | .026 | .009 | .159 | 2.810 | .005 | .524 | 1.908 |
| Neighborhood perception | Presence of destinations in the neighborhood | | -.400 | .203 | -.085 | -1.970 | .049 | .901 | 1.110 |
| | Problems related to automobiles in the neighborhood | | .480 | .190 | .108 | 2.521 | .012 | .911 | 1.098 |
| Walking minutes | Total weekly minutes of walking | | -.403 | .149 | -.115 | -2.700 | .007 | .929 | 1.076 |
| Attitude toward Environment/ Transportation | Preference for walking & biking solve congestion | | -.331 | .196 | -.073 | -1.691 | .091 | .895 | 1.117 |
| Vigorous activity | Total weekly minutes of vigorous activity | | -.188 | .230 | -.035 | -.818 | .414 | .895 | 1.117 |
| Age | Age | | .308 | .120 | .110 | 2.563 | .011 | .909 | 1.100 |
| Gender | Female | | -.952 | .375 | -.107 | -2.538 | .011 | .936 | 1.068 |
| Income | Average yearly household income | | -.248 | .133 | -.080 | -1.863 | .063 | .903 | 1.108 |

Coding and descriptive statistics are available in Tables 3.4 through 3.8.

As shown in Table 4.14, all of the variables were significant except for the total weekly minutes of vigorous activity (p-value= .414) and there were no strong collinearities (Tolerance> 0.2 and VIF< 4.0) among the variables.

***(d) Final Model (Steps 6 & 7)***

Unlike the OLS regression model, such assumptions as normality, linearity, and homogeneity of variance are not necessary for the logistic regression model. The model chi-square was 72.278, which is statistically significant at the 0.01 significance level (Table 4.15). Meanwhile, none of the independent variables in the binary logistic regression model had a standard error of the coefficient (B) greater than 2.0, indicating that there were no strong mulitiollinearities. Operationally, the classification accuracy rate should be 25% or higher than the proportional by chance accuracy. For this model, the classification accuracy was 70.6% which was greater than the criteria (68.9%). The classification accuracy rate is more informative for the reliability of a model than R-square.

From the health status logistic regression model, more parks, street widths, social support in walking and biking in the neighborhood, total weekly minutes of vigorous activity, and education levels increased the probability of the 'excellent' health status. Because more parks promote more walking, biking, and physical activity, the number of parks played a role in increasing health status. Clearly, the presence of social support for walking and biking in the neighborhood promotes those activities and the total weekly minutes of vigorous activity may be a barometer of physical activity. Only the level of education had a positive correlation with health status.

Table 4.15. Built Environmental and Personal Correlates of Health Status and Obesity (Final Model)

| Variable | Measurements | | Health Status B | Health Status Exp(B) | Obesity B | Obesity Beta |
|---|---|---|---|---|---|---|
| Health Status | Perceived health status | | | | -1.177*** | -.243*** |
| Obesity | Body mass index | | -.090*** | .914*** | | |
| Destination | Number of each destination within a 1km network buffer | Churches | | | -.380** | -.133** |
| | | Fast food restaurants | | | .266* | .080* |
| | | Grocery stores | -.116** | .891** | | |
| | | Mixed uses | | | -.952*** | -.165*** |
| | | Museums | | | 1.028** | .101** |
| | | Post offices | -.518** | .596** | | |
| | | Parks | .162** | 1.176** | | |
| Street width | Average number of lanes per way on the street | | .809* | 2.245* | -1.815** | -.121** |
| Traffic speed | Posted traffic speed | | -.104* | .902* | | |
| Bus service | Bus Service: Number of bus stops | | | | .026*** | .159*** |
| Neighborhood perception | Presence of destinations in the neighborhood | | | | -.394* | -.084* |
| | Social support for walking & biking in the neighborhood | | .233** | 1.262** | | |
| | Problems related to automobiles in the neighborhood | | | | .480** | .108** |
| Walking minutes | Total weekly minutes of walking | | | | -.406* | -.116* |
| Attitude toward Environment/ Transportation | Preference for walking & biking to solve congestion | | | | -.357* | -.079* |
| Vigorous activity | Total weekly minutes of vigorous activity | | .386*** | 1.472*** | | |
| Age | Age | | | | .319*** | .114*** |
| Gender | Female | | | | -.934** | -.105** |
| Education | Education level | | .325*** | 1.383*** | | |
| Income | Average yearly household income | | | | -.260* | -.084* |
| Sedentary life | Total weekly minutes of sedentary life at home | | -.247* | .781* | | |
| | Constant coeff. | | 5.913* | 369.633* | 39.252*** | |
| | N | | 503 | | 503 | |
| | $\chi^2$ or F | | $\chi^2$= 72.278 | | F= 7.772 | |
| | Prob.> $\chi^2$ or F | | .000 | | .000 | |
| | Nagelkerke $R^2$ | | .185 | | | |
| | Accuracy rate (>68.9%, criteria) | | 70.6% | | | |
| | $R^2$ | | | | .182 | |
| | Adjust $R^2$ | | | | .159 | |
| | Durbin-Watson | | | | 1.945 | |

* < 0.1 level, **<0.05, and *** < 0.01 level
B: unstandarized coefficient, Beta: standardized coefficient
Coding and descriptive statistics are available in Tables 3.4 through 3.8.

Variables that were negatively related to the probability of ‘excellent’ health status include lower obesity, more grocery stores and post offices, higher traffic speed, and more weekly sedentary minutes at home. Clearly, higher obesity was associated with lower perceived health status. As found in the zip code regression model, the roles of utilitarian facilities on walking, biking, and physical activity would be different depending on the facility and neighborhood types. From this finding, more post offices decreased health status. Faster traffic speed tended to discourage walking and biking. And weekly sedentary minutes at home was a clear barometer for an unhealthy lifestyle.

For the obesity regression model, the overall model fit based on the adjusted R square values was 0.159 and the Durbin-Watson statistic was 1.945, suggesting no serious autocorrelation problems. The normality was checked with a residual histogram and a normal probability plot. The residual histograms did not deviate from normal curve and the residual fell along a straight line. An assumption of constant variance was roughly fitted because the scatterplot had no special pattern (Figure 4.14).

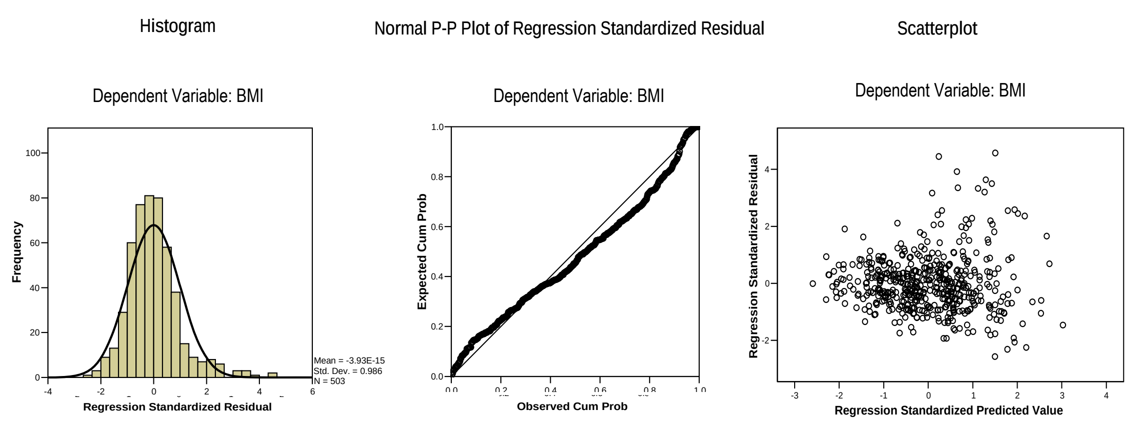


Figure 4.14. Assumption Checks for Regression Models Measuring Obesity at the Individual Level

From the association with obesity, the number of fast food restaurants, museums, bus stops, perceived problems related to automobiles in the neighborhood, and age were positively related with obesity. This is possibly because more fast food restaurants tended to promote unhealthy dietary habits. Both the number of bus stops and perceived problems related to automobiles in the neighborhood could be considered indicators of the intensity of auto-oriented facilities in the neighborhood which reduce walking and jogging. Age is a significant factor because elderly people have difficulty in physical activity and may be more easily disposed to a higher obesity.

Perceived health status, the numbers of churches and mixed use spaces, street width, presence of destinations in the neighborhood, weekly walking minutes, perceived preference for walking and biking to solve congestion, gender, and income level had negative associations with obesity. Churches and mixed use destinations are considered facilities which promote physical activity in this finding. Similar to the previous finding for measuring health status through the binary logistic regression model, the number of lanes is considered an infrastructure which promotes walking, biking, and even physical activity. Clearly, the presence of destinations in the neighborhood and weekly walking minutes were negatively related to obesity. For demographic factors, females and household income level have negative correlation with obesity.

Findings from the correlations of health status and obesity are summarized with four main points. First, there were significant negative correlations between health status and obesity. Health status was negatively associated with obesity measured by body mass index.

Second, the findings supported Hypotheses 3 and 4 that areas with more supportive built environments have higher health status (Hypothesis 3) and lower BMI (Hypothesis 4) than areas with less supportive built environments. The built environmental variables which had positive associations with physical activity included the numbers of churches, mixed use buildings, parks, presence of destinations, and social support for walking and biking in the neighborhood. Built environmental variables which were negatively associated with physical activity were the numbers of museums, post offices, and problems related to automobiles in the neighborhood. With regard to the food environment, access to grocery stores and fast food restaurants had positive associations with unhealthy dietary habits captured by significant relationships between more grocery stores and lower health status and between more fast food restaurants and higher obesity rate.

Third, overall results from the transportation infrastructure did not support the hypothesis, but still made some intuitive sense. Safer environments from traffic and good bus services were hypothesized to be associated with lower obesity rate and higher health status. But the results showed that people living in an area with good transit services had higher BMI and people living in an area with wider streets had higher health status and lower BMI. These findings could be interpreted from the fact that there are uncaputred variations related to socioeconomic factors. For example, higher income people are more likely to have higher health status and lower obesity rate, and they are less likely to use bus service.

Fourth, several demographic and/or individual characteristics were related with health status and obesity. Education level was positively and sedentary life at home was negatively associated with health status. Age had a positive association and the percentage of female and household income had negative relationships with obesity. In addition to the built environment, personal factors had strong associations with health status and obesity.

### 4.3.2.2. Health Disparity at the Individual Level

According to the results of the hot spot analysis in Section 4.3.1, individual health disparities had strong spatial autocorrelations (Moran's I: 0.6071- 0.9286). Because of the evidence of strong spatial autocorrelations, an OLS regression model is insufficient to explain the built environmental and the personal correlates of health disparity. Therefore, this phase employed spatial regression models in addition to the OLS model at the final stage of the analysis process.

#### *(a) Correlation Test with the Selected Variables (Steps 1 & 2)*

Five categories of variables, including health care, food-related, physical activity-related destinations, walking-related and physical activity-related personal factors, and demographics, are included (Table 4.16). Bivariate correlation tests were conducted to determine which variables were significantly related to health status and obesity disparity. These variables are drawn from the conceptual model presented earlier.

Table 4.16. Correlation Test with the Health Disparity

| Variable | Measurements | Health Status Disparity (Gini coefficient) | Obesity Disparity (Gini coefficient) |
|---|---|---|---|
| Health Care Destination | Number of hospitals | -.033 | .031 |
| | Distance to hospital | -.010 | -.133(**) |
| Food-related Destination | Number of grocery stores | -.167(**) | -.085 |
| | Number of fast food restaurants | -.066 | -.037 |
| | Number of bars | -.028 | -.091(*) |
| | Number of convenience stores | .091(*) | .038 |
| | Number of restaurants | -.067 | -.027 |
| | Distance to grocery store | .206(**) | .047 |
| | Distance to fast food restaurant | -.005 | .009 |
| | Distance to bar/tavern | -.003 | .032 |
| | Distance to convenience store | -.102(*) | -.020 |
| | Distance to restaurant | .016 | -.028 |
| Physical Activity-related Destination | Number of parks | -.129(**) | -.010 |
| | Length of regional trail | .011 | .070 |
| | Distance to park | .179(**) | -.013 |
| | Distance to regional trail | -.005 | -.092(*) |
| Walking-related Personal Factor | Total weekly minutes of walking | -.072 | .043 |
| | Walk for recreation | -.058 | .002 |
| | Walk for commuting and to retail services | -.093(*) | -.014 |
| Physical Activity-related Personal Factor | Phase of physical activity at work | .035 | .011 |
| | Total weekly minutes of vigorous activity | -.077 | -.032 |
| | Total weekly minutes of moderate activity | .047 | .067 |
| Demographics | Age | -.023 | .024 |
| | Gender (Female) | -.083 | -.025 |
| | Race (White) | .094(*) | -.066 |
| | Education | -.124(**) | -.080 |
| | Income | -.112(*) | -.165(**) |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Values are Pearson Correlation R.
Coding and descriptive statistics are available in Tables 3.4 through 3.8.

Health status disparity had significant associations with the numbers of and the distances to grocery stores, convenience stores, and parks. Moreover, it is related to walking for commuting and to retail services, white, education, and income. Four variables were related to obesity disparity at the 0.05 level of significance including the number of hospitals, the number of bars, the lengths of regional trails, and income level.

***(b) Correlation Test at the Individual Level (Step 3)***

There were associations within the categories in health status disparity (e.g. number of and distances to grocery stores and convenience stores, food-related destinations; number of and distance to parks, physical activity-related destination; and the percentage of white, education level, and household income, demographics), while there were no strong correlations with the same categories in the obesity disparity.

Because there was no strong correlation within the variables belonging to the same category in obesity disparity, the categorical correlation test shown Table 4.17 was needed only for the health status disparity model. All variables were correlated with others within a category. Thus, one variable per category would be selected for the preliminary model.

Table 4.17. Categorical Correlation Test for Health Disparity Models

| Variable | Measurements | Number of convenience stores | Distance to grocery store | Distance to convenience store | Distance to park | Education | Income |
|---|---|---|---|---|---|---|---|
| Food-related Destination | Number of grocery stores | .180** | -.581** | -.129** | | | |
| | Number of convenience stores | | -.139** | -.678** | | | |
| | Distance to grocery store | | | -.181** | | | |
| Physical Activity-related Destination | Number of parks | | | | -.566** | | |
| Demographics | Race (White) | | | | | .097* | .167** |
| | Education | | | | | | .364** |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

According to the two correlation results in Tables 4.16 and 4.17, the health status disparity model would include at least four variables including walking for commuting and to retail services, and one each one from the selected categories in Table 4.17. Meanwhile, the obesity disparity model would include distances to hospital and regional trails, number of bars, and household income level.

***(c) Preliminary Model (Steps 4 & 5)***

As the measures adjusted R squares indicate, each model has 33.5% and 51.6% evidences of good fit. Durbin-Watson statistics of 1.094 and 0.856 were reported and showed the existence of strong autocorrelations as expected. In addition to the hot spot analysis, the Durbin-Watson for this preliminary model described strong evidence of spatial autocorrelations. Therefore, the introduction of a spatial regression model instead of an OLS model was necessary to analyze individual health disparity.

Table 4.18. Correlates of Health Status Disparity (Preliminary Model)

| Variable | Measurements | | Unstandardized Coefficients B | Unstandardized Coefficients Std. Error | Standardized Coef. Beta | t | Sig. | Collinearity Statistics Tolerance | Collinearity Statistics VIF |
|---|---|---|---|---|---|---|---|---|---|
| | Constant | | .093 | .012 | | 7.952 | .000 | | |
| Distance to downtown | Distance to downtown | | 4.064E-07 | .000 | .499 | 10.364 | .000 | .570 | 1.753 |
| Land use mix | Land use mix | | .016 | .007 | .113 | 2.259 | .024 | .533 | 1.875 |
| Destination | Number of each destination within a 1km network buffer | Parks | -.001 | .000 | -.118 | -2.973 | .003 | .835 | 1.197 |
| | Distance to the closest each destination within a 3km network buffer | Grocery store | .002 | .001 | .106 | 2.485 | .013 | .726 | 1.377 |
| | | Library | -.001 | .000 | -.105 | -2.396 | .017 | .684 | 1.463 |
| | | Museum | .001 | .000 | .080 | 1.749 | .081 | .638 | 1.567 |
| | | School | .003 | .001 | .121 | 3.005 | .003 | .815 | 1.228 |
| | | Theater | -.002 | .001 | -.118 | -2.500 | .013 | .596 | 1.679 |
| Traffic volume | Traffic volume | | -4.571E-07 | .000 | -.218 | -5.259 | .000 | .771 | 1.297 |
| Bus service | Number of bus stops | | 8.223E-05 | .000 | .157 | 3.175 | .002 | .543 | 1.842 |
| Neighborhood perception | Social support for walking & biking in the neighborhood | | -.001 | .001 | -.103 | -2.695 | .007 | .906 | 1.104 |
| | Street amenities in the neighborhood | | .001 | .001 | .088 | 2.219 | .027 | .849 | 1.178 |
| Transportation walk | Walk for commuting and to retail service | | .000 | .001 | -.006 | -.158 | .874 | .836 | 1.196 |
| Race | White | | .006 | .002 | .121 | 3.217 | .001 | .929 | 1.076 |
| Income | Average yearly household income | | -.001 | .000 | -.115 | -2.933 | .004 | .864 | 1.158 |
| Eating out | Average number of eating out per week | | .000 | .000 | .082 | 2.199 | .028 | .947 | 1.056 |

Coding and descriptive statistics are available in Tables 3.4 through 3.8.

From Table 4.18 all selected variables, except for walking for commuting and to retail services, were significant and had no strong collinearities among them. Although walking for commuting and to retail services had a correlation with health status in the third step, it became an insignificant factor in the preliminary regression model. Thus, the final OLS model would be complete only if walking for commuting and to retail services was eliminated.

Table 4.19. Correlates of Obesity Disparity (Preliminary Model)

| Variable | Measurements | | Unstandardized Coefficients | | Standardized Coef. | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|---|
| | | | B | Std. Error | Beta | | | Tolerance | VIF |
| | Constant | | .282 | .030 | | 9.423 | .000 | | |
| Distance to downtown | Distance to downtown | | 5.314E-07 | .000 | .582 | 11.966 | .000 | .408 | 2.452 |
| Land use mix | Land use mix | | .031 | .007 | .198 | 4.243 | .000 | .444 | 2.253 |
| Destination | Number of each destination within a 1km network buffer | Bar | -.001 | .001 | -.031 | -.828 | .408 | .706 | 1.416 |
| | Distance to the closest each destination within a 3km network buffer | Big box retail | -.005 | .001 | -.159 | -4.180 | .000 | .665 | 1.505 |
| | | Day care center | 8.159E-07 | .000 | .133 | 3.744 | .000 | .761 | 1.314 |
| | | Hospital | -.001 | .001 | -.043 | -1.026 | .305 | .550 | 1.819 |
| | | Library | -.003 | .000 | -.353 | -9.306 | .000 | .672 | 1.487 |
| | | Office | .002 | .001 | .116 | 3.028 | .003 | .657 | 1.522 |
| | | Regional shopping center | -.015 | .001 | -.351 | -10.381 | .000 | .846 | 1.182 |
| | | School | .002 | .001 | .064 | 1.750 | .081 | .724 | 1.381 |
| | | Sports facility | -.002 | .000 | -.201 | -5.448 | .000 | .706 | 1.416 |
| | | Theater | .005 | .001 | .324 | 7.450 | .000 | .510 | 1.961 |
| | | Regional trail | -.002 | .001 | -.101 | -3.054 | .002 | .888 | 1.126 |
| Traffic volume | Average traffic volume | | -4.023E-07 | .000 | -.171 | -4.693 | .000 | .726 | 1.377 |
| Bus service | Number of bus stops | | .000 | .000 | .236 | 5.030 | .000 | .439 | 2.276 |
| Sidewalk | Total sidewalk length | | 1.458E-07 | .000 | .137 | 2.983 | .003 | .459 | 2.179 |
| Slope | Mean slope | | .001 | .000 | .172 | 4.177 | .000 | .566 | 1.766 |
| Income | Average yearly household income | | -.001 | .000 | -.060 | -1.842 | .066 | .908 | 1.102 |

Coding and descriptive statistics are available in Tables 3.4 through 3.8.

Similar to the preliminary regression model for health status disparity, the obesity disparity model, shown in Table 4.19, had only two insignificant factors (the number of bars and the distance to hospitals) and no strong collinearity among the variables. Thus, it was necessary to delete these two insignificant variables in accordance with the collinearity check.

***(d) Model Comparison (Step 6)***

Several tests for assumptions showed that the ordinary least square (OLS) model didn’t fit the assumptions. The multicollinearity condition number of 81.846 was greater than criteria of value (20.0) which meant the model had evidence of multicollinearity. The Jarque-Bera test confirmed the non-normal distribution of the error term. However, all the variables didn’t have strong collinearity based on the tolerance rate and VIF (tolerance >.2 and VIF <4). Thus, while there was evidence of multicollinearity and non-normality, the intensity was not strong. According to the Breusch-Pagan and several other spatial dependence tests, there were strong heteroskedasticity and spatial dependence, too. A Moran’s I score of 0.377 indicated evidence of a strong spatial autocorrelation at the 0.01 significance level. Therefore, it became necessary to introduce a spatial regression model (Table 4.20).

The introduction of the spatial regression model improved the general model fit as indicated in the higher values of $R^2$ and Log likelihood (L). For a maximum likelihood (ML) spatial model, the 3km distance spatial weight was used to compute the spatial dependence and correlation. The $R^2$ of OLS, ML spatial lag, and ML spatial error models were 0.357, 0.669, and 0.668, respectively, while the Log likelihood of the model developed from 1532.85 (OLS model) to 1681.07 (LM spatial error model), and even further to 1685.14 (ML spatial lag model). Although introducing the spatial regression model improved the model fit, the characteristics of heteroskedasticity and spatial dependence still existed. P-values of Breusch-Pagan and Likelihood Ratio tests of spatial lag and spatial error models were less than 0.0001. Further, the highly significant parameter of rho (ρ) and lambda (λ) indicated the significant spatial dependencies.

Table 4.20. Built Environmental and Personal Correlates of Health Status Disparity (Model Comparison)

| Variable | Measurements | | OLS | ML Spatial Lag | ML Spatial Error |
|---|---|---|---|---|---|
| Distance to downtown | Distance to Seattle downtown | | 4.064E-07*** | 6.720e-008*** | 1.088e-007 |
| Land use mix | Land use mix | | .016** | .007 | .010 |
| Destination | Number of each destination within a 1km network buffer | Parks | -.001*** | -.001** | -.001* |
| | Distance to the closest each destination within a 3km network buffer | Grocery store | .002** | .001 | .001 |
| | | Library | -.001** | -.001*** | -.001*** |
| | | Museum | .001* | 9.017e-005 | -.001* |
| | | School | .003*** | .001 | .001 |
| | | Theater | -.002** | .001 | .001** |
| Traffic volume | Average traffic volume | | -4.579e-07*** | -2.711e-007*** | -3.029e-007*** |
| Bus service | Number of bus stops | | 8.187e-05*** | 3.392e-005* | 1.700e-005 |
| Neighborhood perception | Social support for walking & biking | | -.002*** | -.001* | -.001 |
| | Street amenities | | .001** | .000 | .000 |
| Race | White | | .006*** | .002 | .002 |
| Income | Average yearly household income | | -.001*** | -.000 | -.000 |
| Eating out | Number of eating outs per week | | .000** | 8.373e-005 | 8.668e-005 |
| | Constant coeff. | | .092*** | .003 | .112*** |
| | Lag Coeff. (Rho) | | | .886*** | |
| | Lambda | | | | .926*** |
| | N | | 503 | 503 | 503 |
| | F | | 17.990 | | |
| | Prob.>F | | .000 | | |
| | $R^2$ | | .357 | .669 | .668 |
| | Likelihood(L) | | 1532.85 | 1685.14 | 1681.07 |
| | (Regression Diagnostics)<br>Multicollinearity condition number<br>Prob. -Jarque-Bera | | <br>81.846<br>.000 | | |
| | (Diagnostics for Heteroskedasticity)<br>Prob. –Breusch-Pagan test | | <br>.000 | <br>.000 | <br>.000 |
| | (Diagnostic for spatial dependence)<br>Moran's I (Prob.)<br>Prob. -Lagrange Multiplier (lag)<br>Prob. -Robust LM (lag)<br>Prob. -Lagrange Multiplier (error)<br>Prob. -Robust LM (error)<br>Prob. -Lagrange Multiplier (SARMA)<br>Prob. -Likelihood Ratio Test | | <br>.377(.000)<br>.000<br>.000<br>.000<br>.000<br>.000<br> | <br><br><br><br><br><br><br>.000 | <br><br><br><br><br><br><br>.000 |

* < 0.1 level, **<0.05, and *** < 0.01 level
Coding and descriptive statistics are available in Tables 3.4 through 3.8.

Similar to the health status disparity model, the OLS regression in obesity disparity had multicollinearity, non-normality, heterosckedasticy, and strong spatial dependencies. These limitations necessitated the introduction of the spatial regression model instead of an OLS regression model (Table 4.21). The model fit improved through the spatial regression models. The $R^2$ increased from 0.531 to 857and the Log likelihood also improved from 1554.88 to 1860.09. However, there still existed spatial dependencies according to the Likelihood Ratio test. Moreover, the spatial autoregressive coefficients in spatial lag and spatial error models (e.g., $\rho=0.953$, p-value<0.001; $\lambda=0.983$, p-value<0.001) were highly significant.

The spatial regression model brought an improvement of general model fit even though it didn't remove the spatial effect. From the multivariate statistical models estimating the levels of health disparities, the spatial regression models significantly improve the overall model fit when compared to the OLS models. However, the Likelihood Ratio test and the parameters of rho (ρ) and lambda (λ) pointed to continued spatial dependencies. The ML spatial lag model would be the best model to use based on the model performance parameters (e.g. $R^2$ and Log likelihood).

Table 4.21. Built Environment and Personal Correlates of Obesity Disparity at the Individual Level (Model Comparison)

| Variable | Measurements | | OLS | ML Spatial Lag | ML Spatial Error |
|---|---|---|---|---|---|
| Distance to downtown | Distance to Seattle downtown | | 5.372e-07*** | 7.294e-008*** | -2.890e-007** |
| Land use mix | Land use mix | | .032*** | .0126*** | .016** |
| Destination | Distance to the closest each destination within a 3km network buffer | Big box retail | -.005*** | -.001** | .000 |
| | | Day care | 8.222e-07*** | 3.159e-007*** | 1.360e-007 |
| | | Library | -.003*** | -.002*** | -.001*** |
| | | Office | .002*** | .001*** | .001** |
| | | Regional shopping center | -.015*** | -.004*** | -.001 |
| | | School | .002* | .001*** | .001* |
| | | Sports facility | -.002*** | -6.235e-005 | -.000 |
| | | Theater | .005*** | .002*** | .002*** |
| | | Trail | -.002*** | -4.713e-005 | .000 |
| Traffic volume | Average traffic volume | | -4.177e-07*** | -2.812e-007*** | -2.563e-007*** |
| Bus service | Number of bus stops | | .000*** | 3.221e-005** | 2.564e-005 |
| Sidewalk | Length of sidewalk | | 1.633e-07*** | 5.417e-008*** | 5.354e-008*** |
| Slope | Mean slope | | .001*** | .000* | .000** |
| Income | Average yearly household income | | -.001* | -.000 | -.000 |
| | Constant coeff. | | .267*** | .038*** | .092*** |
| | Lag Coeff. (Rho) | | | .959*** | |
| | Lambda | | | | .983*** |
| | N | | 503 | 503 | 503 |
| | F | | 34.448 | | |
| | Prob.>F | | .000 | | |
| | $R^2$ | | .531 | .873 | .857 |
| | Likelihood(L) | | 1554.88 | 1860.09 | 1824.53 |
| | (Regression Diagnostics)<br>Multicollinearity condition number<br>Prob. -Jarque-Bera | | <br>225.196<br>.000 | | |
| | (Heteroskedasticity test)<br>Prob. -Breusch-Pagan test | | <br>.000 | <br>.000 | <br>.000 |
| | (Diagnostic for spatial dependence)<br>Moran's I (Prob.)<br>Prob. -Lagrange Multiplier (lag)<br>Prob. -Robust LM (lag)<br>Prob. -Lagrange Multiplier (error)<br>Prob. -Robust LM (error)<br>Prob. -Lagrange Multiplier (SARMA)<br>Prob. -Likelihood Ratio Test | | <br><br>.369(.000)<br>.000<br>.000<br>.000<br>.000<br>.000 | <br><br><br><br><br><br><br>.000 | <br><br><br><br><br><br><br>.000 |

* < 0.1 level, **<0.05, and *** < 0.01 level
Coding and descriptive statistics are available in Tables 3.4 through 3.8.

***(e) Final Model (Step 7)***

The overall findings of the health disparity using ML spatial lag regression analysis (shown in Table 4.22) are summarized as follows.

First, health disparity was positively related to the distance to downtown. Areas near downtown Seattle had small street blocks, high density, and promoted physical activity. This finding supported the hypothesis that areas with supportive built environments promoting physical activity have lower health disparity. This falls in with the previous findings of hot spot and the zip code level correlation analyses.

Second, land use mix, range zero (single use) to one (perfect mixing) was positively associated with obesity disparity. It meant that mixed used areas tended to have higher obesity disparity. This finding is in disagreement with the previous results which found that hot spots of health status disparity had fewer numbers of mixed use destinations.

Third, supportive built environmental destinations which promote physical activity had a lower disparity. Supportive built environmental destinations included easy access to parks, offices, and schools, whereas less supportive destination included libraries. Destinations of parks, offices, and schools tended to produce commuting and recreational trips and therefore promote physical activity. Thus, this finding supported the hypothesis that an area with supportive built environment should have lower health disparity.

Fourth, big box shopping centers, including big box retail and regional shopping centers, had positive correlations with health disparity. It is consistent with the findings from the hot spot analysis at the individual level and the bivariate correlation at the zip code level.

Fifth, easy access to day care centers and theaters was negatively related to health disparity. This is different from the finings of bivariate analysis at the zip code level. The numbers of day care centers and theaters were positively related to health disparity at the zip code level bivariate correlation analysis.

Sixth, health disparity had positive relationships with the number of bus stops, sidewalk length, and the mean slope while it was negatively related to traffic volume. Some findings didn't support the hypothesis that areas with supportive built environments which promote physical activity have a lower health disparity. The sidewalk and the bus stop could be considered as built environmental features which promote walking and biking; i.e. the usage of public transportation would produce walking. And higher traffic volume should indicate a higher percentage of automobile travel. Thus, these findings didn't support the hypothesis.

Seventh, health disparity was negatively related to the neighborhood perception of social support for waking and biking. It is consistent with the bivariate correlation analysis at the zip code level.

Table 4.22. Built Environment and Personal Correlates of Health Disparity (Final Model)

| Variable | Measurements | | Health Status Disparity | Obesity Disparity |
|---|---|---|---|---|
| Distance to downtown | Distance to Seattle downtown | | 6.720e-008*** | 7.294e-008*** |
| Land use mix | Land use mix | | .007 | .0126*** |
| Destination | Number of each destination with a 1km network buffer | Park | -.001** | |
| | Distance to the closest each destination within a 3km network buffer | Big box retail | | -.001** |
| | | Day care center | | 3.159e-007*** |
| | | Grocery Store | .001 | |
| | | Library | -.001*** | -.002*** |
| | | Museum | 9.017e-005 | |
| | | Office | | .001*** |
| | | Regional shopping center | | -.004*** |
| | | School | .001 | .001*** |
| | | Sports facility | | -6.235e-005 |
| | | Theater | .001 | .002*** |
| | | Trail | | -4.713e-005 |
| Traffic volume | Average traffic volume | | -2.711e-007*** | -2.812e-007*** |
| Bus service | Number of bus stops | | 3.392e-005* | 3.221e-005** |
| Sidewalk | Length of sidewalk | | | 5.417e-008*** |
| Slope | Mean slope | | | .000* |
| Neighborhood perception | Social support for walking and biking | | -.001* | |
| | Street amenities | | .000 | |
| Race | White | | .002 | |
| Income | Average yearly household income | | -.000 | -.000 |
| Eating out | Number of eating outs per week | | 8.373e-005 | |
| | Constant coeff. | | .003 | .038*** |
| | Lag Coeff. (Rho) | | .886*** | .959*** |
| | N | | 503 | 503 |
| | $R^2$ | | .669 | .873 |
| | Likelihood(L) | | 1685.14 | 1860.09 |

* < 0.1 level, **<0.05, and *** < 0.01 level
Coding and descriptive statistics are available in Tables 3.4 through 3.8.

In sum, the built environmental correlates of disparities in health status and obesity are synthetically summarized again as follows.

The overall findings supported the first hypothesis in that the areas with more supportive built environments which promote physical activity have a lower health disparity than areas with less supportive built environments. From the spatial regression model, variables which indicated supportive environmental conditions included easy access to destinations such as parks, offices, schools, being closer to downtown, and increased neighborhood perception of social support for waking and biking. However, there were some results which differed from the previous studies in the hot spot analysis at the individual level and the bivariate correlation analysis at the zip code level. They included health disparity being correlated with the land use mix (+), access to day care centers (–), theaters (–), traffic volume (–), bus stops (+), and sidewalk length (+).

The overall findings show that the role of the built environment may be more important than personal factors. No socioeconomic factors were shown to be associated with health disparity in the spatial regression models.

**4.3.2.3. Conclusion**

This study confirms that the built environment significantly and strongly influenced perceived health status, obesity, and health disparity. In addition to the findings from the bivariate analysis at the zip code level in the previous section, this multivariate and disaggregated analysis clearly confirms again that built environments which promote physical activity and healthy dietary habits increase health status, reduce obesity, and decrease health disparity.

The validity of the findings from this study is considered high, because of the detailed data capturing and methodology in modeling. First, this level used all the individual data directly from the survey as run through a 3km buffering measure from the GIS database. Modeling using the individual unit of analysis is an ideal approach for understanding what influences each individual. Second, this study addressed the spatial autocorrelation of interdependence and interaction among the spatial entities, explored the spatial autocorrelation, and introduced regulation skills. Traditional linear regression models cannot control for the spatial effects of the data which were collected based on spatial attributes. The existence of spatial autocorrelations was described through data mapping (e.g. GIS maps), Moran's I, LISA maps, and Moran scatter plots in Section 3.2. Furthermore, this study developed spatial error and spatial lag models in addition to the OLS regression model, and selected the best model from three.

This study provides insight into the relationship between the built environment and health disparity and further suggests policy recommendations for designers, planners, and even politicians.

# CHAPTER V

# CONCLUSIONS AND DISCUSSION

Reducing or eliminating health disparity is one of the top agendas of public health research in the US; as a result, many research institutes have made it their primary goal to achieve in the near future. The U.S. Department of Health and Human Services report clearly describes health disparity as follows.

> A health disparity is an inequality or gap that exists between two or more groups. Health disparities are believed to be the result of the complex interaction of personal, societal, and environmental factors. (Healthy People in Healthy Communities, February, 2001)

This dissertation study brings attention to the problem of health disparity in the US, and adds to the previous literature on health, physical activity, and obesity by focusing on the issues of geographic inequality. The above statement and a literature review of health disparity describe the cause not as a single factor, but as multiple attributes among individual, social, and environmental factors. More research is needed to investigate the various aspects of disparity and unequal health burdens related to the built environment. This dissertation research pays attention to the role of the built environment on health disparity and suggests an objective body of evidence for proposing relevant public policies and programs. This conclusion chapter presents an overall summary of the dissertation research findings pertaining to these specific aims. Moreover, this chapter discusses additional findings and policy implications. It concludes by suggesting future research guidelines in addition to the limitations of this research.

### 5.1. Conclusions

Most health disparity literature relied on simple descriptive statistics to measure disparity. The regional disparity literature tends to address much larger geographic areas and focuses on disparities in income and job opportunities. Many studies have used the Gini coefficient as a measure not only of income inequality, but also of health disparity. Because of the popularity, efficiency, and effectiveness in quantifying disparity, this empirical study employed the Gini coefficient as a measure. The review of literature demonstrates that the built environment significantly correlates with levels of obesity, physical activity, dietary habits, and even health disparity. Because all these elements are interconnected, a multidisciplinary approach was proposed and further tested a series of hypotheses for the specific aims in this dissertation work.

#### 5.1.1. Aim One

The empirical investigation on the trend in the magnitude of health disparity (aim one study) showed that all states had a gradual increase in health disparity by BMI, and all but three States (District of Columbia, Hawaii and North Dakota) showed an increase in health disparity by perceived health status. Patterns of health disparities were similar to the obesity trend published by the CDC. As of 2004, Kentucky, Mississippi, West Virginia, Alabama, Tennessee, and Oklahoma were rated the top six in health status related disparity, and the States of Ohio, Mississippi, Alabama, Tennessee, Louisiana, and West Virginia in the BMI related disparity. Most of the States ranked high in health disparity had more than 25% rates in obesity prevalence. GIS maps are used to visually represent these longitudinal trends as well as the relative magnitudes in health disparity across the states in the US.

After controlling for demographic covariates, health status disparity negatively correlated with the percentage of high school or higher level, median household income, and the percentage of population using public transportation; it had positive associations with the percentage of the population below the poverty level. BMI disparity had negative correlations with the percentage of high school or higher level, median household income, and the percentage of white population; it also had a positive relationship with the percentage of population below the poverty level. Several variables, including population density, median age, and car ownership, didn’t have any strong association with disparity in health. States high in health disparity tended to be correlated with low education and income levels, and high rates of population below poverty.

### 5.1.2. Aims Two and Three

The overall findings of the studies for the second and third aims are shown in Tables 5.1 and 5.2 and are further summarized with the following points. First, the distance to downtown was a significant factor not only on the clusters of higher levels of health disparity (e.g. hot spots) but also on health disparity itself. The further from downtown Seattle, the more hot spots agglomerated and the higher individual health disparities became. This finding should be directly applied to policy implications for balancing plans between downtowns and surrounding areas.

Table 5.1. Overall Results of Aim Two

| Variable | Measurements | | Health Status Disparity | | Obesity Disparity | |
|---|---|---|---|---|---|---|
| | | | Hot spot | Cold spot | Hot spot | Cold spot |
| Distance to downtown | Distance to Seattle downtown | | + | | + | |
| Destination | Number of each destination within a 1km network buffer | Church | − | | − | |
| | | Grocery store | − | | | |
| | | Mixed use | − | | | |
| | | Museum | | | − | |
| | | Office | | | − | |
| | | Regional shopping center | | | + | |
| | | Retail store | | | − | |
| | | Theater | | | − | |
| | Distance to the closest each destination within a 3km network buffer | Church | + | | | |
| | | Neighborhood/community shopping center | − | | | + |
| | | Grocery store | + | | | |
| | | Library | + | | | |
| | | Museum | + | | + | − |
| | | Regional shopping center | | | − | |
| | | School | + | | | |
| | | Theater | | | + | |
| Street length | Total length of street | | − | | | |
| Sign | Number of traffic signs | | − | | | |
| Sidewalk | Total sidewalk length | | − | | | |
| Intersection | Number of intersections | | − | | | |
| Education | Phase of education | | − | | | |
| Income | Average yearly household income | | | | − | + |

Coding and descriptive statistics are available in Tables 3.4 through 3.8.

Second, destinations which support or encourage physical activity were correlated with increased health status, reduced obesity, and reduced health disparity. Supportive built environment destinations included churches, mixed use spaces, offices, parks, museums, and schools. Conversely, destinations such as banks, post offices, neighborhood/community shopping centers, regional shopping centers, and big box retail stores were negatively related to health status and positively related to both obesity and health disparity. Depending on the types and sizes, the roles of utilitarian destinations on health outcomes are different. From this study, banks and post offices are considered less supportive built environmental features. Moreover, big box shopping centers are considered less supportive built environments.

Third, the food environment is another significant factor relating health disparity in addition to health status and obesity prevalence. Supportive food environments only included grocery stores while less supportive food destinations included fast food restaurants, two types of neighborhood centers used for convenience stores, restaurants, grocery stores, and fast food restaurants. Generally, grocery stores provide healthy foods such as fruits and vegetables, while fast food restaurants and convenience stores supply high-fat and high-sugar foods. This finding described that neighborhood centers used for food facilities played as non-supportive built environment although a single destination was supportive (e.g. grocery stores were supportive environments in the previous findings). Overall, the second and third findings supported the hypotheses that areas with supportive built environments which increase physical activity and healthy dietary habits have a lower health disparity, higher health status, and lower obesity rate than areas with less supportive built environments.

Table 5.2. Overall Results of Aim Three

| Variable | Measurement | | Bivariate Correlation Analysis at the Zip Code Level | | | | Multivariate Regression Analysis at the Individual Level | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Health Status | Obesity | Health Status Disparity | Obesity Disparity | Health Status | Obesity | Health Status Disparity | Obesity Disparity |
| Health status | Perceived health status | | | | | | | – | | |
| Obesity | Body mass index | | | | | | – | | | |
| Distance to downtown | Distance to Seattle downtown | | | + | + | + | | | + | + |
| Land use mix | Land use mix | | | | | | | | | + |
| Destination | Number of each destination within a 1km network buffer | Bank | | + | + | | | | | |
| | | Big box retail | | + | | | | | | |
| | | Church | | | | | | – | | |
| | | Neigh./ community shopping center | | + | + | | | | | |
| | | Convenience store | | + | + | | | | | |
| | | Day care center | | + | + | | | | | |
| | | Fast food restaurant | | + | + | | | + | | |
| | | Grocery store | | – | | | – | | | |
| | | Mixed use | | – | | | | – | | |
| | | Museum | | | | | | + | | |
| | | Post office | | | + | | – | | | |
| | | Regional shopping center | | + | | | | | | |
| | | Theater | | | + | | | | | |
| | | Park | | | | | + | | – | |
| | Number of each neighborhood center (NC) within a 1km network buffer | NC used for convenience stores, restaurants, and grocery stores | | | + | + | | | | |
| | | NC used for offices and mixed uses | | – | | | | | | |
| | | NC used for sports facilities and schools | | | – | | | | | |
| | | NC used for convenience stores, fast food restaurants, and grocery stores | | + | + | | | | | |
| | Distance to the closest each destination within 3km network buffer | Big box retail | | | | | | | | – |
| | | Day care center | | | | | | | | + |
| | | Library | | | | | | | – | – |
| | | Office | | | | | | | | + |
| | | Regional shopping center | | | | | | | | – |
| | | School | | | | | | | | + |
| | | Theater | | | | | | | | + |

Table 5.2. (Continued)

| Variable | Measurement | Bivariate Correlation Analysis at the Zip Code Level | | | | Multivariate Regression Analysis at the Individual Level | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Health Status | Obesity | Health Status Disparity | Obesity Disparity | Health Status | Obesity | Health Status Disparity | Obesity Disparity |
| Street length | Total length of street | | + | + | + | | | | |
| Street width | Average number of lanes per way on the street | | | | | + | − | | |
| Traffic speed | Posted traffic speed | | + | + | + | − | | | |
| Traffic volume | Traffic volume | | | | | | | − | − |
| Bus service | Number of bus stops | | | | | | + | + | + |
| Sign | Number of traffic signs | | + | + | | | | | |
| Sidewalk | Total sidewalk length | | | | | | | | + |
| Intersection | Number of intersections | − | | + | + | | | | |
| Slope | Mean slope | | | | | | | | + |
| Neighborhood perception | Presence of destinations in the neighborhood | | | | | | − | | |
| | Social support for walking and biking in the neighborhood | | − | − | | + | | − | |
| | Presence of amenities for biking and jogging in the neighborhood | | − | | | | | | |
| | Problems related to automobiles in the neighborhood | | | | | | + | | |
| Walking minutes | Total weekly minutes of walking | + | − | | | | − | | |
| Recreation walk | Walk for recreation | | | − | | | | | |
| Transportation walk | Walk for commuting and to retail services | + | − | − | | | | | |
| Transit use | Transit User | + | − | | | | | | |
| Attitude toward environment/transportation | Preference for walking and biking to solve congestion | | − | | | | − | | |
| Vigorous activity | Total weekly minutes of vigorous activity | | | | | + | | | |
| Moderate activity | Total weekly minutes of moderate activity | | − | | | | | | |
| Car ownership | Number of cars in household | − | | | | | | | |
| Age | Age | − | | | | | + | | |
| Gender | Female | | − | | | | − | | |
| Race | White | | | + | | | | | |
| Education | Phase of education | | − | − | − | + | | | |
| Income | Average yearly household income | | | | − | | − | | |
| Sedentary life | Total weekly minutes of sedentary life at home | | | | | − | | | |

Coding and descriptive statistics are available in Tables 3.4 through 3.8.

Fourth, health disparity had positive associations with objectively measured infrastructure. According to the results of the hot spot analysis, the areas with hot spot of health status disparity had less street length, traffic signs, sidewalk length, and intersections than the cold spot areas. However, from the correlation test at the zip code level and the regression analysis at the individual model, the overall findings agreed that health disparity had positive associations with objectively measured infrastructure including street and sidewalk lengths, traffic speed, and the numbers of bus stops, traffic signs, and intersections. Depending on the analysis and the type, the relationships between infrastructure and health status, obesity, and health disparity was different. However, the multivariate regression analysis at the individual level is the most reliable among three analyses, because it controlled other confounding variables.

Fifth, although there were no significant neighborhood perception variables in the hot spot analysis, several were significant on the correlation at the zip code level and the regression model at the individual level. These variables included the presence of destinations, social support for walking and biking, presence of amenities for biking and jogging, and problems related to automobiles in the neighborhood. Thus, not only the objective measures, but also subjective measures were important factors on health outcome and health disparity.

Sixth, many demographic factors that were expected to be strongly correlated with health disparity were not necessarily significant. Only the household income variable possessed a strong effect on the correlation analysis, regression models, and hot spot analysis; other variables such as age, gender, race, and education were not primary factors on health status, obesity, or even health disparity. Overall, this finding confirmed the hypotheses that the role of the built environment, as opposed to demographic factors, was much stronger in health disparity.

## 5.2. Discussion

### 5.1.1. Additional Findings

In addition to the major findings corresponding to the specific aims, there are several additional findings from this research as follows.

First, the neighborhood district, a locally defined administrative boundary within Seattle, was a significant factor for obesity disparity. The average obesity disparities in the Ballard, Southwest, and Northwest areas were significantly higher than the citywide average. In contrast, the obesity disparity in the Northeast area was lower than the citywide average. Most significant differences among those neighborhood districts were that the Ballard, Southwest, and Northwest had low levels of income disparity whereas the Northeast district had high income disparity.

Second, there was strong spatial autocorrelation for health disparity at the individual level. It meant that there were strong spatial clustering patterns of high disparity and low disparity areas across different geographic regions. Because of the strong spatial autocorrelation, the spatial regression model was used instead of the OLS regression analysis to verify the model assumptions including uncorrelated error terms and independent observations; this spatial regression model improved the general model fit when compared to the alternative.

Third, there were different results for the transportation infrastructure variables between bivariate and multivariate analyses. The bivariate correlation results supported the hypothesis that the areas with unsafe environments captured by longer street, higher traffic speed, and more traffic signs and intersections were negatively related with health status or positively related with obesity and health disparity. However, transportation infrastructure variables from the multivariate analysis did not support the hypothesis due to uncaptured variations related with socioeconomic factors, but had intuitively correct direction of association with health status, obesity, and health disparity. Findings did not support the hypothesis that areas with less traffic and with higher public transportation usage were positively related with health status and negatively associated with obesity and health disparity. Potentially, people with high-income were more likely to use their own cars instead of bus service, therefore their neighborhood was more likely to have higher traffic volume and wider street system. However, they were likely to have higher health status and lower obesity.

Fourth, the dissertation research addresses the spatial scale issues that are important in quantitative analysis dealing with environmental data. Researcher should deal with spatial scale problems since the spatial unit of analysis can seriously distort final results (Openshaw and Alvandies, 1999). This dissertation research starts to consider and address the Modifiable Areal Unit Problem (MAUP) which is one of spatial scale problems. There are two main components of MAUP including the scale effect occurring due to the numbers of zones used in an analysis and the aggregation effect arising when the small areas are grouped into larger units (Armhein, 1995). For the scale problem, this dissertation study considered three types of weight matrices (definition of neighbors) to measure the spatial dependency in hot spot analysis. For the aggregation problem, this study avoided MAUP for individual level of analysis, although this problem is still present in the zip code level analysis, as it aggregates the individual survey data up to the zip code area.

### 5.1.2. Policy Recommendations

One of the aims of this dissertation is to provide policy suggestions for increasing health status, reducing obesity, and alleviating health disparity. According to the findings of this study, several policy implications can be suggested.

First, health disparity should be added as a measure of leading health indicators for local and national health policies. According to Healthy People 2010, there are ten leading health indicators[4] for gauging and promoting health status; the publication also outlines their trends, current status, and future goals in these indicators. The findings of this research used perceived health status and obesity measured by BMI as health indicators and showed that health disparity has clearly increased during the last ten years. Health disparity can be added as a measure of these ten indicators and appropriate regulations for reducing the level of disparity should be established. Moreover, equity is an important issue in economics, sociology, public health, and urban planning. More rigorous surveillance systems is needed to better understand the spatial and longitudinal patterns of disparity and help develop short and long-term strategies to reduce health disparity. In sum, the current efforts to reduce obesity should incorporate paralleled strategies to reduce disparities in obesity.

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[4] They include (1) physical activity, (2) overweight and obesity, (3) tobacco use, (4) substance abuse, (5) responsible sexual behavior, (6) mental health, (7) injury and violence, (8) environmental quality, (9) immunization, and (10) access to care.

Second, federal-level efforts seem necessary for controlling the high significantly health levels of disparity and obesity prevalence in the southern states. The findings in Section 4.1 clearly describe that the highest intensity of disparity in health is in the southern US. Actions by the regional and federal governments in the south should include building their own customized strategies for more effectively controlling the prevalence of health disparity. These strategies should consider the specific socio cultural and environmental conditions of these states. Governments can earmark subsidies and investments for controlling geographical differences in health disparity. Further, collaborations among different governmental agencies and different departments within a local jurisdiction would be important to bring the health agenda back into the urban planning policy decision process.

Third, policies for balancing between downtown districts and surrounding areas may be effective in reducing health disparity. According to sub-section in 5.1, the distance to the downtown area is one of the most significant factors related to health disparity. The further from the downtown, the more hot spots in health disparity clustered and the higher health disparity was. Major causes of the differences in health disparity are differences in the built environment in addition to socioeconomic factors according to the main findings of this dissertation. Therefore, policies that facilitate investments in areas with poor infrastructure and the tools to systematically assess the qualities of the existing infrastructure can help reduce disparities in the long term.

Fourth, as this and other studies found that land use is significantly associated with health status and health disparity, land use policies should start considering their public health implications more seriously. Further, current land use policies such as zoning, are too general or broad to effectively address the public health goals. For example, different types of destinations are shown to have different directions of correlation with health and health disparity. This dissertation finds that churches, mixed used buildings, offices, parks, museums, and schools are positively banks, post offices, neighborhood/community shopping centers, regional shopping center, big box retail stores, and fast food restaurants are negatively correlated with health disparity. So, land use policies should specify the types of land use in much greater detail to help promote healthier and more equitable environments. Both regulatory and incentive-based strategies are needed to promote a healthy mix of land uses in urban neighborhoods. For example, development impact fees for the land uses that promote healthy lifestyle and reduce disparities may be reduced or waived, while the other types of land uses may be charged with additional health impact fees. Another example is to suggest land use policies to promote locating churches, mixed building, offices, museums, and schools in close proximity to residential areas, and to help locate recreation facilities such as park near residential areas.

Fifth, this dissertation research brings the necessity of transportation policies. There are obvious linkages between physical activity and obesity prevalence. Physical inactivity is related with higher level of obesity rate in addition to higher food consumption (Hill and Peters, 1998; Poston and Foreyt, 1999). The current epidemic of obesity is largely caused by an environment that promotes excessive food intake and discourages physical activity. This research reviewed the literature dealing with the built environment – physical activity relationship that was one of main components of the conceptual framework in this dissertation. Especially, walking and biking were suggested as important physical activities to reduce obesity rate. Moreover, transportation infrastructure such as street length, traffic speed, traffic volume, and the numbers of signs and intersection were significantly correlated with perceived health status, obesity, and health disparity from the second and third aims results. It means that both non-motorized and motorized transportation policies should respond to the need for promoting health status, reducing obesity, and reducing health disparity.

### 5.1.3. Limitations and Future Study Suggestions

Although this study provides a greater understanding of the role of the built environment on health disparity, it marks only the beginning in investigation of the relationship between the two. This study has several limitations leading to suggest further directions for future study.

First, a more detailed and relevant unit of analysis could be developed to measure the built environment. Even though the zip code is efficient for policy implications, a better definition of neighborhoods is needed to better track the built environmental correlates of health outcomes. Thus one of the next steps is to develop a more relevant neighborhood definitions and related spatial units for measuring the built environment's impacts on health disparity for developing evidence-based policies.

Second, other health and disease incidences as indicators for health disparity can be considered. Objective indicators can better stand for health status and more useful for policy purposes compared to self-reported indicators. For example, more objective indicators such as type 2 diabetes, cardiovascular disease, health care expenditures, and clinic utilization can be included in future study.

Third, other methods for measuring health disparity can be considered. Many studies have used the Gini coefficient as a measure of regional income inequality and health disparity. Although the Gini coefficient is the most popular measure for disparity, it does not have consider the socioeconomic dimensions. Concentration coefficients could be employed to measure the health disparity in addition to the Gini coefficient.

Fourth, a study of the correlation between health disparity and economic development could be another topic for future research. Literature in regional science has shown that there was inverted-U pattern between regional income disparity and economic development level and further identified augmented inverted U-pattern at the end of inverted-U curve (Kuznets, 1955; Willamson, 1965; Amos, 1988). This empirical study can be applied in health disparity research to identify whether patterns of inverted-Us and/or augmented inverted-Us exist between health disparity and economic development. The results can suggest policy recommendations to reduce health disparity by varying economic policies such as distribution of resources and investments.

Fifth, this research can be extended to multilevel analysis. To simultaneously examine associations between variables measured from two different spatial units, it can employ a Hierarchical Linear Model (HLM) identifying the group-level built environmental correlates of health disparity, obesity, and health status, controlling for demographic and social environmental (individual-level) variables. The results can offer stronger insights into the environmental variables that may promote good health, reduce obesity, and to reduce health disparity. Because health status and BMI are influenced by factors that operate at the individual and group levels, and because the individual level variables are nested within the group, HLM provides a valid technique for examining the impact of multi-level factors on the dependent variable.

Sixth, there could be potential causal relations among the dependent variables. There are sequential relations among objectively measured, subjectively measured, and behavioral built environmental variables that are correlated with health conditions. Common quantitative methods used in this dissertation such as correlation, analysis of variance (ANOVA), and multiple regression models cannot detect the causality with cross-sectional data. In order to build a causal modeling, Structural Equation Modeling (SEM) with longitudinal data may be an option for future research.

Seventh, limitation related to the previous point is its cross sectional design. Thus, it cannot identify causal relationship between built environment and health disparity over time. For example, the construction of infrastructure and neighborhood commercial centers may be reflected in differences in individuals' perceived health status and obesity at some future point in time. Moreover, the longitudinal trend of the relationship between the built environment and health disparity is more valuable for recommending policy implications. Thus, to better capture the built environment-health disparity relationship, a longitudinal study is preferred.

Eighth, it is necessary to consider more social and cultural factors in a diverse community. The location of this research is Seattle and its surrounding area; this makes the study limited to a high percentage of white populations and urbanized areas. Potential future studies could cover more diverse rural environments and communities with high percentage of minority populations and low-income groups.

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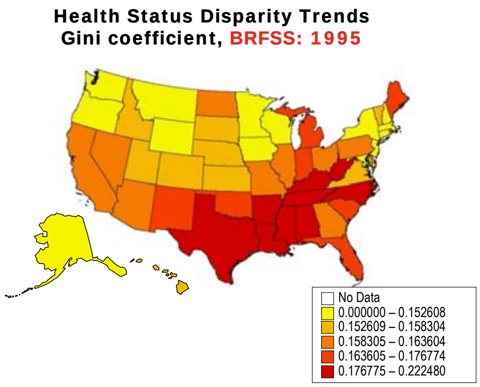
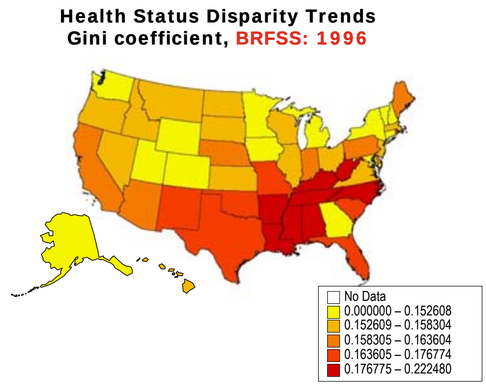
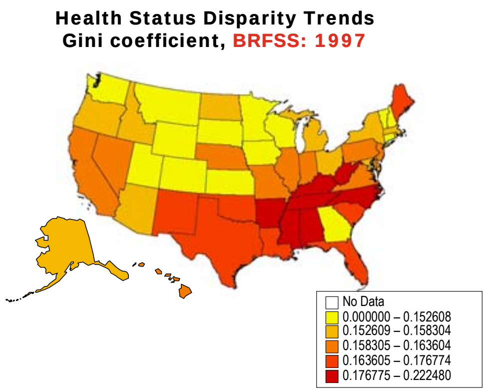
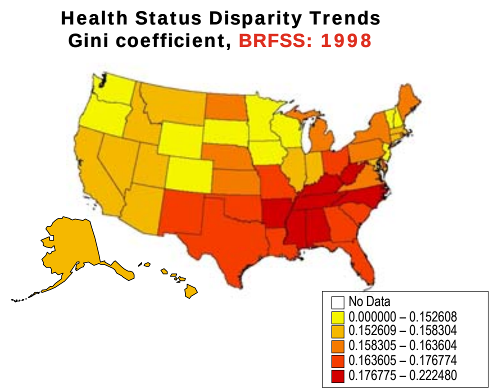
# APPENDIX

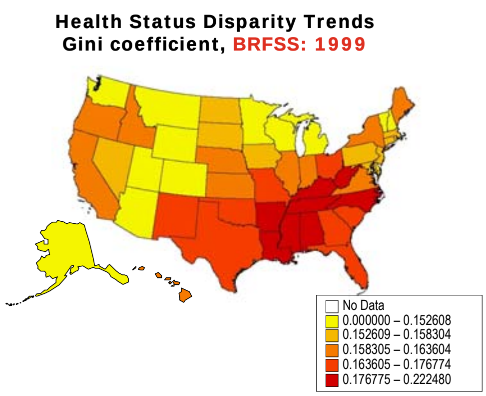
# Appendix 1. Health Disparity Trends between 1995 and 2004

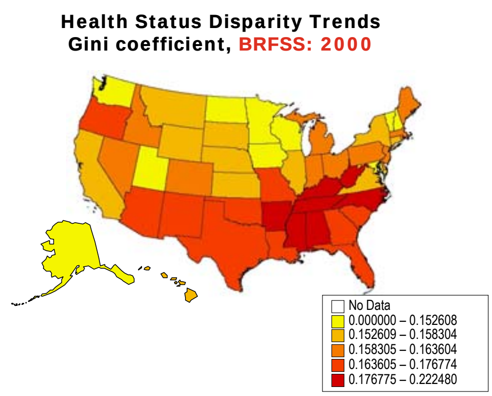


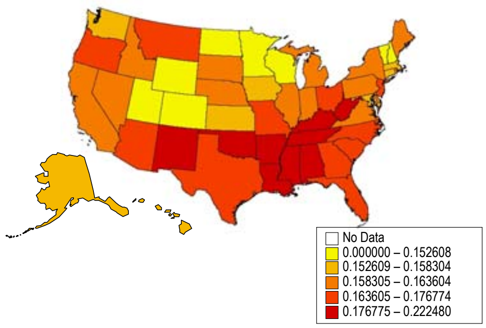



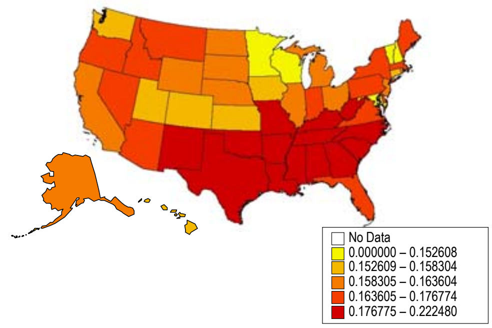



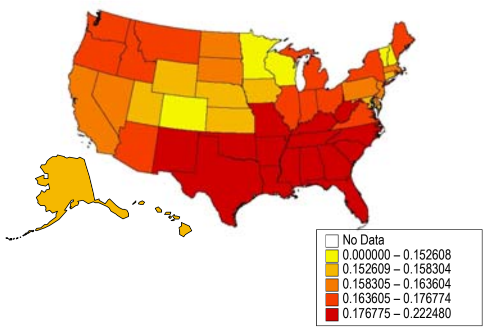
**Health Status Disparity Trends**
**Gini coefficient, BRFSS: 2001**



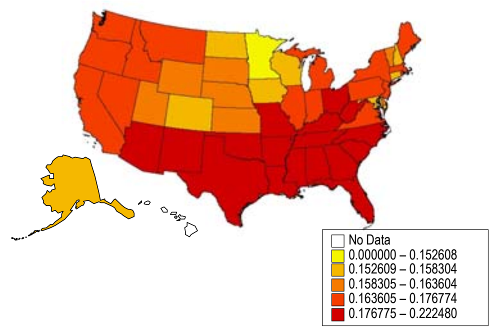

**Health Status Disparity Trends**
**Gini coefficient, BRFSS: 2002**

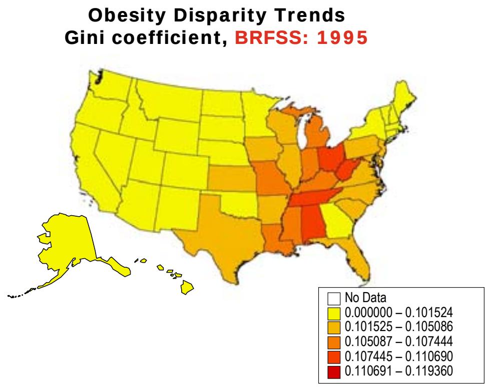


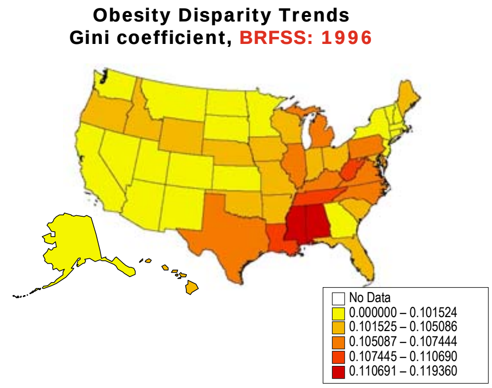

**Health Status Disparity Trends**
**Gini coefficient, BRFSS: 2003**




**Health Status Disparity Trends**
**Gini coefficient, BRFSS: 2004**




Obesity Disparity Trends
Gini coefficient, BRFSS: 1995
No Data
0.000000 – 0.101524
0.101525 – 0.105086
0.105087 – 0.107444
0.107445 – 0.110690
0.110691 – 0.119360


Obesity Disparity Trends
Gini coefficient, BRFSS: 1996
No Data
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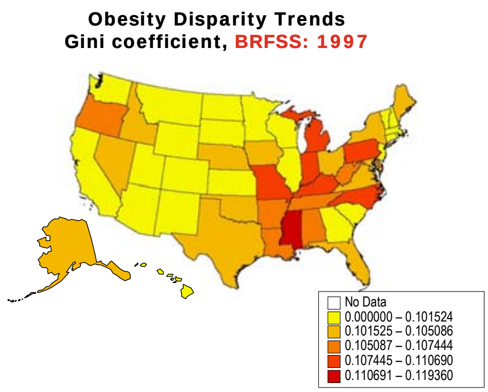
0.101525 – 0.105086
0.105087 – 0.107444
0.107445 – 0.110690
0.110691 – 0.119360


Obesity Disparity Trends
Gini coefficient, BRFSS: 1997
No Data
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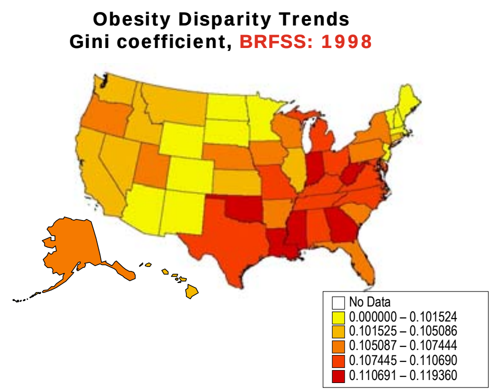
0.101525 – 0.105086
0.105087 – 0.107444
0.107445 – 0.110690
0.110691 – 0.119360


Obesity Disparity Trends
Gini coefficient, BRFSS: 1998
No Data
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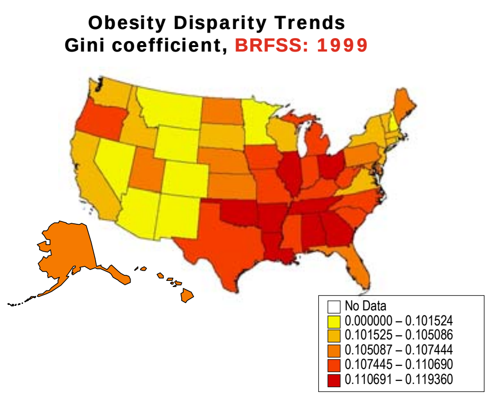
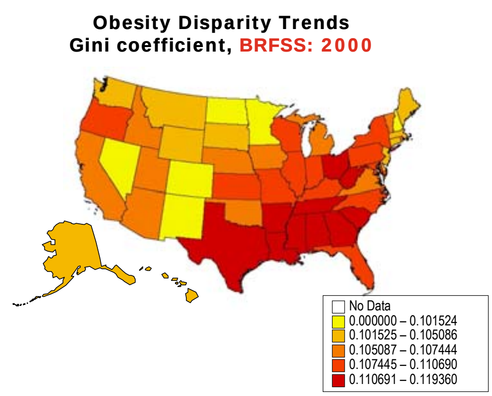
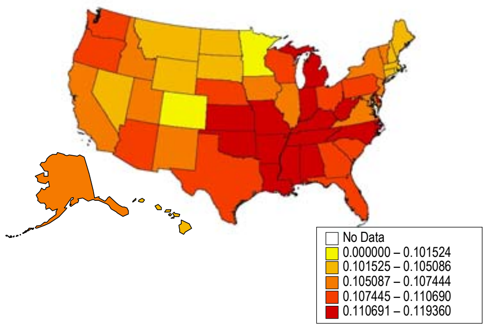
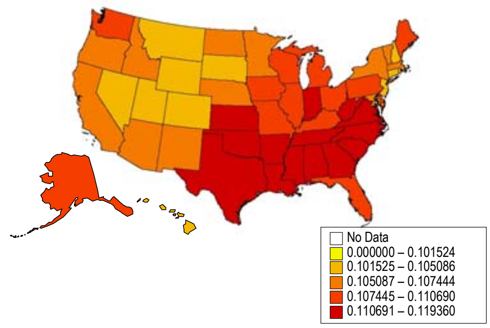

Obesity Disparity Trends
Gini coefficient, BRFSS: 1999
No Data
0.000000 – 0.101524
0.101525 – 0.105086
0.105087 – 0.107444
0.107445 – 0.110690
0.110691 – 0.119360


Obesity Disparity Trends
Gini coefficient, BRFSS: 2000
No Data
0.000000 – 0.101524
0.101525 – 0.105086
0.105087 – 0.107444
0.107445 – 0.110690
0.110691 – 0.119360

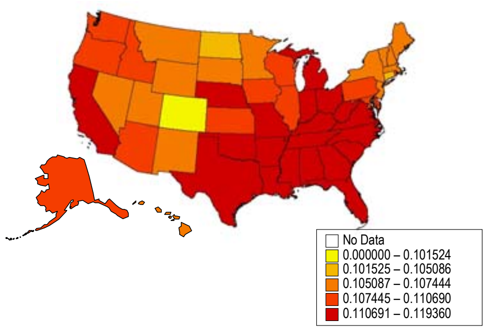
**Obesity Disparity Trends**
**Gini coefficient, BRFSS: 2001**



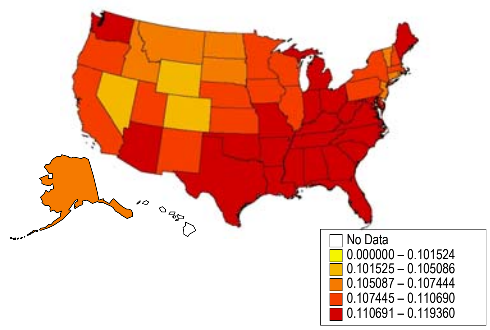

**Obesity Disparity Trends**
**Gini coefficient, BRFSS: 2002**




**Obesity Disparity Trends**
**Gini coefficient, BRFSS: 2003**




**Obesity Disparity Trends**
**Gini coefficient, BRFSS: 2004**



# Appendix 2. Descriptive Statistics of Spatial Weight Matrices

## 2.1. Health Status Disparity: 4-nearest Neighbors Spatial Weight

Table 2.1. Descriptive Statistics

| | Section | Variable/Measurements | | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Lower Bound | Upper Bound | | |
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Not sig | 403 | 23542.00 | 12195.47 | 607.50 | 22347.73 | 24736.27 | 490.53 | 56718.34 |
| | | | | Hotspot | 42 | 61912.95 | 27763.24 | 4283.96 | 53261.32 | 70564.59 | 12616.18 | 118740.06 |
| | | | | Coldspot | 57 | 22886.13 | 11249.86 | 1490.08 | 19901.14 | 25871.12 | 11031.61 | 50030.52 |
| | | | | Total | 502 | 26677.85 | 17612.21 | 786.07 | 25133.45 | 28222.25 | 490.53 | 118740.06 |
| | | Number of each destination within a 1km network buffer | Church | Not sig | 403 | 12.27 | 1.59 | .08 | 12.11 | 12.42 | 10.00 | 17.00 |
| | | | | Hotspot | 42 | 10.98 | .81 | .13 | 10.72 | 11.23 | 10.00 | 13.00 |
| | | | | Coldspot | 57 | 11.72 | 1.29 | .17 | 11.38 | 12.06 | 10.00 | 15.00 |
| | | | | Total | 502 | 12.10 | 1.56 | .07 | 11.96 | 12.23 | 10.00 | 17.00 |
| | | | Grocery store | Not sig | 403 | 12.54 | 1.92 | .10 | 12.35 | 12.72 | 10.00 | 16.00 |
| | | | | Hotspot | 42 | 10.48 | .63 | .10 | 10.28 | 10.67 | 10.00 | 12.00 |
| | | | | Coldspot | 57 | 11.42 | 1.28 | .17 | 11.08 | 11.76 | 10.00 | 15.00 |
| | | | | Total | 502 | 12.24 | 1.89 | .08 | 12.07 | 12.40 | 10.00 | 16.00 |
| | | | Mixed use | Not sig | 403 | 11.31 | .73 | .04 | 11.24 | 11.38 | 10.00 | 14.00 |
| | | | | Hotspot | 42 | 10.55 | .50 | .08 | 10.39 | 10.70 | 10.00 | 11.00 |
| | | | | Coldspot | 57 | 10.98 | .92 | .12 | 10.74 | 11.23 | 10.00 | 13.00 |
| | | | | Total | 502 | 11.21 | .77 | .03 | 11.14 | 11.28 | 10.00 | 14.00 |
| | | Distance to the closest each destination within a 3km network buffer | Church | Not sig | 403 | 7.24 | .70 | .03 | 7.17 | 7.31 | 4.26 | 9.18 |
| | | | | Hotspot | 42 | 7.65 | .79 | .12 | 7.40 | 7.90 | 5.15 | 8.80 |
| | | | | Coldspot | 57 | 7.40 | .83 | .11 | 7.17 | 7.62 | 5.25 | 9.03 |
| | | | | Total | 502 | 7.29 | .73 | .03 | 7.23 | 7.36 | 4.26 | 9.18 |
| | | | Neighborhood/ community shopping center | Not sig | 403 | 13.79 | 1.88 | .09 | 13.61 | 13.98 | 10.00 | 16.00 |
| | | | | Hotspot | 42 | 12.40 | 1.58 | .24 | 11.91 | 12.90 | 10.00 | 16.00 |
| | | | | Coldspot | 57 | 13.44 | 1.94 | .26 | 12.92 | 13.95 | 10.00 | 16.00 |
| | | | | Total | 502 | 13.64 | 1.90 | .08 | 13.47 | 13.80 | 10.00 | 16.00 |
| | | | Grocery store | Not sig | 403 | 7.57 | .63 | .03 | 7.51 | 7.63 | 4.80 | 8.98 |
| | | | | Hotspot | 42 | 8.25 | .67 | .10 | 8.05 | 8.46 | 6.46 | 9.19 |
| | | | | Coldspot | 57 | 7.78 | .78 | .10 | 7.58 | 7.99 | 4.44 | 8.89 |
| | | | | Total | 502 | 7.65 | .68 | .03 | 7.59 | 7.71 | 4.44 | 9.19 |
| | | | Library | Not sig | 403 | 12.70 | 1.60 | .08 | 12.55 | 12.86 | 10.00 | 16.00 |
| | | | | Hotspot | 42 | 14.05 | 1.89 | .29 | 13.46 | 14.64 | 11.00 | 16.00 |
| | | | | Coldspot | 57 | 13.04 | 1.69 | .22 | 12.59 | 13.48 | 10.00 | 16.00 |
| | | | | Total | 502 | 12.85 | 1.68 | .07 | 12.71 | 13.00 | 10.00 | 16.00 |
| | | | Museum | Not sig | 403 | 11.82 | 1.41 | .07 | 11.68 | 11.95 | 10.00 | 14.00 |
| | | | | Hotspot | 42 | 13.45 | 1.19 | .18 | 13.08 | 13.82 | 10.00 | 14.00 |
| | | | | Coldspot | 57 | 12.05 | 1.11 | .15 | 11.76 | 12.35 | 10.00 | 14.00 |
| | | | | Total | 502 | 11.98 | 1.43 | .06 | 11.85 | 12.11 | 10.00 | 14.00 |
| | | | School | Not sig | 403 | 7.50 | .62 | .03 | 7.44 | 7.56 | 4.22 | 9.18 |
| | | | | Hotspot | 42 | 7.84 | .75 | .12 | 7.60 | 8.07 | 5.24 | 8.91 |
| | | | | Coldspot | 57 | 7.57 | .71 | .09 | 7.38 | 7.76 | 5.90 | 8.97 |
| | | | | Total | 502 | 7.54 | .65 | .03 | 7.48 | 7.59 | 4.22 | 9.18 |
| | Objective Measure & Infrastructure | Street length | Total street length | Not sig | 403 | 105189.80 | 29484.14 | 1468.71 | 102302.49 | 108077.11 | 14972.10 | 197338.90 |
| | | | | Hotspot | 42 | 58931.25 | 21668.18 | 3343.47 | 52178.97 | 65683.53 | 18230.70 | 103929.40 |
| | | | | Coldspot | 57 | 85106.05 | 32905.84 | 4358.48 | 76374.95 | 93837.14 | 23569.40 | 138407.60 |
| | | | | Total | 502 | 99039.14 | 32316.58 | 1442.36 | 96205.32 | 101872.96 | 14972.10 | 197338.90 |
| | | Sign | Number of traffic signs | Not sig | 403 | 2.01 | 1.06 | .05 | 1.90 | 2.11 | .00 | 4.85 |
| | | | | Hotspot | 42 | 1.28 | .92 | .14 | .99 | 1.57 | .00 | 3.37 |
| | | | | Coldspot | 57 | 1.65 | 1.04 | .14 | 1.37 | 1.92 | .00 | 3.87 |
| | | | | Total | 502 | 1.91 | 1.07 | .05 | 1.81 | 2.00 | .00 | 4.85 |
| | | Sidewalk length | Total sidewalk length | Not sig | 403 | 38475.08 | 14052.60 | 700.01 | 37098.94 | 39851.22 | .00 | 76162.20 |
| | | | | Hotspot | 42 | 19087.12 | 12446.44 | 1920.53 | 15208.54 | 22965.70 | 325.10 | 54646.50 |
| | | | | Coldspot | 57 | 32756.26 | 15427.23 | 2043.39 | 28662.86 | 36849.65 | 11970.50 | 83974.80 |
| | | | | Total | 502 | 36203.63 | 15092.94 | 673.63 | 34880.14 | 37527.12 | .00 | 83974.80 |
| | | Intersection | Number of intersections | Not sig | 403 | 148.09 | 50.85 | 2.53 | 143.11 | 153.07 | 11.00 | 269.00 |
| | | | | Hotspot | 42 | 73.74 | 31.33 | 4.83 | 63.98 | 83.50 | 19.00 | 148.00 |
| | | | | Coldspot | 57 | 112.88 | 53.30 | 7.06 | 98.74 | 127.02 | 20.00 | 222.00 |
| | | | | Total | 502 | 137.87 | 54.52 | 2.43 | 133.09 | 142.65 | 11.00 | 269.00 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | Not sig | 403 | 5.75 | .95 | .05 | 5.65 | 5.84 | 3.00 | 7.00 |
| | | | | Hotspot | 42 | 5.24 | .88 | .14 | 4.96 | 5.51 | 3.00 | 7.00 |
| | | | | Coldspot | 57 | 5.88 | .89 | .12 | 5.64 | 6.11 | 4.00 | 7.00 |
| | | | | Total | 502 | 5.72 | .95 | .04 | 5.64 | 5.80 | 3.00 | 7.00 |

Table 2.2. Test of Homogeneity of Variances

| | Section | Variable/Measurement | | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|---|---|---|
| Built. Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | 30.701 | 2 | 499 | .000 |
| | | Number of each destination within a 1km network buffer | Church | 5.501 | 2 | 499 | .004 |
| | | | Grocery store | 30.869 | 2 | 499 | .000 |
| | | | Mixed use | 1.537 | 2 | 499 | .216 |
| | | Distance to the closest each destination within a 3km network buffer | Church | 2.630 | 2 | 499 | .073 |
| | | | Neighborhood/ community shopping center | 2.612 | 2 | 499 | .074 |
| | | | Grocery store | .486 | 2 | 499 | .615 |
| | | | Library | 3.750 | 2 | 499 | .024 |
| | | | Museum | 11.745 | 2 | 499 | .000 |
| | | | School | 2.965 | 2 | 499 | .052 |
| | Objective Measure & Infrastructure | Street length | Total street length | 3.324 | 2 | 499 | .037 |
| | | Sign | Number of traffic signs | .310 | 2 | 499 | .734 |
| | | Sidewalk length | Total sidewalk length | .502 | 2 | 499 | .606 |
| | | Intersection | Number of intersections | 6.339 | 2 | 499 | .002 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | .612 | 2 | 499 | .543 |

Table 2.3. Kruskal Wallis Test

| | Section | Variable/Measurements | | Chi-Square | df | Asymp. Sig. |
|---|---|---|---|---|---|---|
| Built. Env. | Objective Measure and Land Use | Distance to downtown | Distance to Seattle downtown | 90.222 | 2 | 0.000 |
| | | Number of each destination within a 1km network buffer | Church | 40.731 | 2 | 0.000 |
| | | | Grocery store | 65.193 | 2 | 0.000 |
| | | | Mixed use | 50.665 | 2 | 0.000 |
| | | Distance to the closest each destination within a 3km network buffer | Church | 15.302 | 2 | 0.000 |
| | | | Neighborhood/ community shopping center | 19.818 | 2 | 0.000 |
| | | | Grocery store | 43.720 | 2 | 0.000 |
| | | | Library | 19.430 | 2 | 0.000 |
| | | | Museum | 51.005 | 2 | 0.000 |
| | | | School | 11.936 | 2 | 0.003 |
| | Objective Measure & Infrastructure | Street length | Total street length | 82.620 | 2 | 0.000 |
| | | Sign | Number of traffic signs | 21.383 | 2 | 0.000 |
| | | Sidewalk length | Total sidewalk length | 65.411 | 2 | 0.000 |
| | | Intersection | Number of intersections | 83.017 | 2 | 0.000 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | 14.316 | 2 | 0.001 |

Table 2.4. ANOVA

| | Section | Variable/Measurements | | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|---|---|
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Between Groups | 56925936786.053 | 2 | 28462968393.026 | 144.223 | .000 |
| | | | | Within Groups | 98479265737.023 | 499 | 197353237.950 | | |
| | | | | Total | 155405202523.075 | 501 | | | |
| | | Number of each destination within a 1km network buffer | Church | Between Groups | 72.335 | 2 | 36.167 | 15.816 | .000 |
| | | | | Within Groups | 1141.076 | 499 | 2.287 | | |
| | | | | Total | 1213.410 | 501 | | | |
| | | | Grocery store | Between Groups | 204.192 | 2 | 102.096 | 32.070 | .000 |
| | | | | Within Groups | 1588.599 | 499 | 3.184 | | |
| | | | | Total | 1792.791 | 501 | | | |
| | | | Mixed use | Between Groups | 25.422 | 2 | 12.711 | 23.526 | .000 |
| | | | | Within Groups | 269.616 | 499 | .540 | | |
| | | | | Total | 295.038 | 501 | | | |
| | | Distance to the closest each destination within a 3km network buffer | Church | Between Groups | 7.053 | 2 | 3.527 | 6.736 | .001 |
| | | | | Within Groups | 261.232 | 499 | .524 | | |
| | | | | Total | 268.285 | 501 | | | |
| | | | Neighborhood/ community shopping center | Between Groups | 75.643 | 2 | 37.822 | 10.880 | .000 |
| | | | | Within Groups | 1734.645 | 499 | 3.476 | | |
| | | | | Total | 1810.289 | 501 | | | |
| | | | Grocery store | Between Groups | 19.143 | 2 | 9.572 | 22.422 | .000 |
| | | | | Within Groups | 213.014 | 499 | .427 | | |
| | | | | Total | 232.157 | 501 | | | |
| | | | Library | Between Groups | 70.989 | 2 | 35.495 | 13.236 | .000 |
| | | | | Within Groups | 1338.103 | 499 | 2.682 | | |
| | | | | Total | 1409.092 | 501 | | | |

Table 2.4. (Continued)

| | Section | Variable/Measurements | | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Museum | Between Groups | 102.142 | 2 | 51.071 | 27.531 | .000 |
| | | | | Within Groups | 925.659 | 499 | 1.855 | | |
| | | | | Total | 1027.801 | 501 | | | |
| | | | School | Between Groups | 4.419 | 2 | 2.210 | 5.389 | .005 |
| | | | | Within Groups | 204.594 | 499 | .410 | | |
| | | | | Total | 209.013 | 501 | | | |
| | Objective Measure & Infrastructure | Street length | Total street length | Between Groups | 93874211986.364 | 2 | 46937105993.182 | 54.551 | .000 |
| | | | | Within Groups | 429350762119.307 | 499 | 860422368.977 | | |
| | | | | Total | 523224974105.671 | 501 | | | |
| | | Sign | Number of traffic signs | Between Groups | 24.343 | 2 | 12.171 | 11.102 | .000 |
| | | | | Within Groups | 547.080 | 499 | 1.096 | | |
| | | | | Total | 571.422 | 501 | | | |
| | | Sidewalk length | Total sidewalk length | Between Groups | 15061625561.316 | 2 | 7530812780.658 | 37.934 | .000 |
| | | | | Within Groups | 99064589118.463 | 499 | 198526230.698 | | |
| | | | | Total | 114126214679.779 | 501 | | | |
| | | Intersection | Number of intersections | Between Groups | 250433.540 | 2 | 125216.770 | 50.440 | .000 |
| | | | | Within Groups | 1238771.044 | 499 | 2482.507 | | |
| | | | | Total | 1489204.584 | 501 | | | |
| Personal Factor | Demographics/ Individual Characteristics | Education | Education | Between Groups | 11.453 | 2 | 5.727 | 6.495 | .002 |
| | | | | Within Groups | 439.943 | 499 | .882 | | |
| | | | | Total | 451.396 | 501 | | | |

Table 2.5. Homogeneous Subsets

| | Section | Variable/Measurements | | | N | Subset for alpha = .05 | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 2 | 3 |
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Cold spot | 57 | 22886.13 | | |
| | | | | Not sig. | 403 | 23542.00 | | |
| | | | | Hot spot | 42 | | 61912.95 | |
| | | | | Sig. | | .785 | 1.000 | |
| | | Number of each destination within a 1km network buffer | Church | Hot spot | 42 | 10.98 | | |
| | | | | Cold spot | 57 | | 11.72 | |
| | | | | Not sig. | 403 | | | 12.27 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Grocery store | Hot spot | 42 | 10.48 | | |
| | | | | Cold spot | 57 | | 11.42 | |
| | | | | Not sig. | 403 | | | 12.54 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Mixed use | Hot spot | 42 | 10.55 | | |
| | | | | Cold spot | 57 | | 10.98 | |
| | | | | Not sig. | 403 | | | 11.31 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | Distance to the closest each destination within a 3km network buffer | Church | Not sig. | 403 | 7.24 | | |
| | | | | Cold spot | 57 | 7.40 | | |
| | | | | Hot spot | 42 | | 7.65 | |
| | | | | Sig. | | .215 | 1.000 | |
| | | | Neighborhood/ community shopping center | Hot spot | 42 | 12.40 | | |
| | | | | Cold spot | 57 | | 13.44 | |
| | | | | Not sig. | 403 | | 13.79 | |
| | | | | Sig. | | 1.000 | .269 | |
| | | | Grocery store | Not sig. | 403 | 7.57 | | |
| | | | | Cold spot | 57 | 7.78 | | |
| | | | | Hot spot | 42 | | 8.25 | |
| | | | | Sig. | | .052 | 1.000 | |
| | | | Library | Not sig. | 403 | 12.7022 | | |
| | | | | Cold spot | 57 | 13.0351 | | |
| | | | | Hot spot | 42 | | 14.0476 | |
| | | | | Sig. | | .235 | 1.000 | |
| | | | Museum | Not sig. | 403 | 11.8164 | | |
| | | | | Cold spot | 57 | 12.0526 | | |
| | | | | Hot spot | 42 | | 13.4524 | |
| | | | | Sig. | | .311 | 1.000 | |
| | | | School | Not sig. | 403 | 7.5013 | | |
| | | | | Cold spot | 57 | 7.5722 | | |
| | | | | Hot spot | 42 | | 7.8392 | |
| | | | | Sig. | | .518 | 1.000 | |

Table 2.5. (Continued)

| | Section | Variable/Measurements | | | N | Subset for alpha = .05 | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 2 | 3 |
| | Objective Measure & Infrastructure | Street length | Total street length | Hot spot | 42 | 58931.25 | | |
| | | | | Cold spot | 57 | | 85106.05 | |
| | | | | Not sig. | 403 | | | 105189.80 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | Sign | Number of traffic signs | Hot spot | 42 | 1.28 | | |
| | | | | Cold spot | 57 | | 1.65 | |
| | | | | Not sig. | 403 | | | 2.01 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | Sidewalk length | Total sidewalk length | Hot spot | 42 | 19087.12 | | |
| | | | | Cold spot | 57 | | 32756.26 | |
| | | | | Not sig. | 403 | | | 38475.08 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | Intersection | Number of intersections | Hot spot | 42 | 73.74 | | |
| | | | | Cold spot | 57 | | 112.88 | |
| | | | | Not sig. | 403 | | | 148.09 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | Hot spot | 42 | 5.24 | | |
| | | | | Not sig. | 403 | | 5.75 | |
| | | | | Cold spot | 57 | | 5.88 | |
| | | | | Sig. | | 1.000 | .417 | |

## 2.2. Health Status Disparity: 10-nearest Neighbors Spatial Weight

Table 2.6. Descriptive Statistics

| | Section | Variable/Measurements | | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Lower Bound | Upper Bound | | |
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Not sig. | 307 | 20913.03 | 10427.04 | 595.10 | 19742.01 | 22084.04 | 490.53 | 53727.91 |
| | | | | Hot spot | 87 | 49591.82 | 24392.33 | 2615.13 | 44393.11 | 54790.53 | 12616.18 | 118740.06 |
| | | | | Cold spot | 99 | 22994.95 | 10554.91 | 1060.81 | 20889.81 | 25100.09 | 9586.56 | 50030.52 |
| | | | | Total | 493 | 26392.06 | 17607.99 | 793.02 | 24833.93 | 27950.20 | 490.53 | 118740.06 |
| | | Number of each destination within a 1km network buffer | Church | Not sig. | 307 | 12.44 | 1.70 | .10 | 12.25 | 12.63 | 10.00 | 17.00 |
| | | | | Hot spot | 87 | 11.17 | .85 | .09 | 10.99 | 11.35 | 10.00 | 13.00 |
| | | | | Cold spot | 99 | 11.84 | 1.14 | .11 | 11.61 | 12.07 | 10.00 | 15.00 |
| | | | | Total | 493 | 12.10 | 1.56 | .07 | 11.96 | 12.23 | 10.00 | 17.00 |
| | | | Grocery store | Not sig. | 307 | 12.68 | 1.95 | .11 | 12.46 | 12.90 | 10.00 | 16.00 |
| | | | | Hot spot | 87 | 11.02 | 1.27 | .14 | 10.75 | 11.29 | 10.00 | 15.00 |
| | | | | Cold spot | 99 | 12.01 | 1.67 | .17 | 11.68 | 12.34 | 10.00 | 16.00 |
| | | | | Total | 493 | 12.25 | 1.89 | .09 | 12.09 | 12.42 | 10.00 | 16.00 |
| | | | Mixed use | Not sig. | 307 | 11.35 | .69 | .04 | 11.27 | 11.43 | 10.00 | 13.00 |
| | | | | Hot spot | 87 | 10.75 | .53 | .06 | 10.63 | 10.86 | 10.00 | 12.00 |
| | | | | Cold spot | 99 | 11.20 | 1.01 | .10 | 11.00 | 11.40 | 10.00 | 14.00 |
| | | | | Total | 493 | 11.22 | .77 | .03 | 11.15 | 11.28 | 10.00 | 14.00 |
| | | Distance to the closest each destination within a 3km network buffer | Church | Not sig. | 307 | 7.21 | .66 | .04 | 7.14 | 7.29 | 4.26 | 8.77 |
| | | | | Hot spot | 87 | 7.54 | .73 | .08 | 7.39 | 7.70 | 5.15 | 9.18 |
| | | | | Cold spot | 99 | 7.30 | .90 | .09 | 7.12 | 7.48 | 4.36 | 9.03 |
| | | | | Total | 493 | 7.29 | .74 | .03 | 7.22 | 7.35 | 4.26 | 9.18 |
| | | | Neighborhood/ community shopping center | Not sig. | 307 | 13.95 | 1.78 | .10 | 13.75 | 14.15 | 10.00 | 16.00 |
| | | | | Hot spot | 87 | 12.37 | 1.82 | .20 | 11.98 | 12.76 | 10.00 | 16.00 |
| | | | | Cold spot | 99 | 13.90 | 1.87 | .19 | 13.53 | 14.27 | 10.00 | 16.00 |
| | | | | Total | 493 | 13.66 | 1.90 | .09 | 13.49 | 13.83 | 10.00 | 16.00 |
| | | | Grocery store | Not sig. | 307 | 7.55 | .62 | .04 | 7.48 | 7.62 | 4.80 | 8.98 |
| | | | | Hot spot | 87 | 7.98 | .75 | .08 | 7.82 | 8.14 | 5.96 | 9.19 |
| | | | | Cold spot | 99 | 7.64 | .71 | .07 | 7.49 | 7.78 | 4.44 | 8.89 |
| | | | | Total | 493 | 7.64 | .68 | .03 | 7.58 | 7.70 | 4.44 | 9.19 |
| | | | Library | Not sig. | 307 | 12.55 | 1.49 | .09 | 12.38 | 12.72 | 10.00 | 16.00 |
| | | | | Hot spot | 87 | 13.79 | 1.98 | .21 | 13.37 | 14.21 | 10.00 | 16.00 |
| | | | | Cold spot | 99 | 12.90 | 1.59 | .16 | 12.58 | 13.22 | 10.00 | 16.00 |
| | | | | Total | 493 | 12.84 | 1.67 | .08 | 12.69 | 12.99 | 10.00 | 16.00 |
| | | | Museum | Not sig. | 307 | 11.68 | 1.36 | .08 | 11.53 | 11.83 | 10.00 | 14.00 |
| | | | | Hot spot | 87 | 13.06 | 1.43 | .15 | 12.75 | 13.36 | 10.00 | 14.00 |
| | | | | Cold spot | 99 | 11.88 | 1.15 | .12 | 11.65 | 12.11 | 10.00 | 14.00 |
| | | | | Total | 493 | 11.96 | 1.43 | .06 | 11.84 | 12.09 | 10.00 | 14.00 |
| | | | School | Not sig. | 307 | 7.45 | .60 | .03 | 7.38 | 7.52 | 4.22 | 9.05 |
| | | | | Hot spot | 87 | 7.84 | .69 | .07 | 7.69 | 7.99 | 5.24 | 9.18 |
| | | | | Cold spot | 99 | 7.51 | .66 | .07 | 7.38 | 7.65 | 5.90 | 8.97 |
| | | | | Total | 493 | 7.53 | .65 | .03 | 7.47 | 7.59 | 4.22 | 9.18 |
| | Objective Measure & Infrastructure | Street length | Total street length | Not sig. | 307 | 110186.12 | 28429.70 | 1622.57 | 106993.32 | 113378.92 | 17988.50 | 197338.90 |
| | | | | Hot spot | 87 | 68596.14 | 23976.45 | 2570.55 | 63486.07 | 73706.22 | 14972.10 | 108711.30 |
| | | | | Cold spot | 99 | 93027.23 | 31429.90 | 3158.82 | 86758.64 | 99295.81 | 23569.40 | 141383.30 |
| | | | | Total | 493 | 99401.01 | 32380.50 | 1458.34 | 96535.66 | 102266.36 | 14972.10 | 197338.90 |
| | | Sign | Number of traffic signs | Not sig. | 307 | 2.11 | 1.10 | .06 | 1.99 | 2.24 | .00 | 4.85 |
| | | | | Hot spot | 87 | 1.42 | .86 | .09 | 1.23 | 1.60 | .00 | 3.53 |
| | | | | Cold spot | 99 | 1.72 | .97 | .10 | 1.52 | 1.91 | .00 | 3.87 |
| | | | | Total | 493 | 1.91 | 1.07 | .05 | 1.82 | 2.01 | .00 | 4.85 |
| | | Sidewalk length | Total sidewalk length | Not sig. | 307 | 39576.87 | 13833.93 | 789.54 | 38023.25 | 41130.50 | 3983.30 | 76162.20 |
| | | | | Hot spot | 87 | 25302.88 | 14233.56 | 1526.00 | 22269.30 | 28336.46 | 325.10 | 54646.50 |
| | | | | Cold spot | 99 | 35664.79 | 14957.87 | 1503.32 | 32681.49 | 38648.08 | 9143.50 | 83974.80 |
| | | | | Total | 493 | 36272.34 | 15072.22 | 678.82 | 34938.60 | 37606.08 | 325.10 | 83974.80 |
| | | Intersection | Number of intersections | Not sig. | 307 | 156.05 | 49.65 | 2.83 | 150.47 | 161.62 | 15.00 | 269.00 |
| | | | | Hot spot | 87 | 88.22 | 34.73 | 3.72 | 80.82 | 95.62 | 14.00 | 156.00 |
| | | | | Cold spot | 99 | 129.04 | 53.80 | 5.41 | 118.31 | 139.77 | 11.00 | 230.00 |
| | | | | Total | 493 | 138.66 | 54.57 | 2.46 | 133.83 | 143.48 | 11.00 | 269.00 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | Not sig. | 307 | 5.76 | .95 | .05 | 5.66 | 5.87 | 3.00 | 7.00 |
| | | | | Hot spot | 87 | 5.45 | .94 | .10 | 5.25 | 5.65 | 3.00 | 7.00 |
| | | | | Cold spot | 99 | 5.83 | .92 | .09 | 5.65 | 6.01 | 4.00 | 7.00 |
| | | | | Total | 493 | 5.72 | .95 | .04 | 5.64 | 5.80 | 3.00 | 7.00 |

Table 2.7. Test of Homogeneity of Variances

| | Section | Variable/Measurement | | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|---|---|---|
| Built. Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | 20.672 | 2 | 490 | .000 |
| | | Number of each destination within a 1km network buffer | Church | 17.557 | 2 | 490 | .000 |
| | | | Grocery store | 22.266 | 2 | 490 | .000 |
| | | | Mixed use | 11.073 | 2 | 490 | .000 |
| | | Distance to the closest each destination within a 3km network buffer | Church | 5.594 | 2 | 490 | .004 |
| | | | Neighborhood/ community shopping center | .416 | 2 | 490 | .660 |
| | | | Grocery store | 3.555 | 2 | 490 | .029 |
| | | | Library | 15.231 | 2 | 490 | .000 |
| | | | Museum | 5.581 | 2 | 490 | .004 |
| | | | School | 3.444 | 2 | 490 | .033 |
| | Objective Measure & Infrastructure | Street length | Total street length | 3.509 | 2 | 490 | .031 |
| | | Sign | Number of traffic signs | 1.719 | 2 | 490 | .180 |
| | | Sidewalk length | Total sidewalk length | .182 | 2 | 490 | .834 |
| | | Intersection | Number of intersections | 7.594 | 2 | 490 | .001 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | .596 | 2 | 490 | .551 |

Table 2.8. Kruskal Wallis Test

| | Section | Variable/Measurements | | Chi-Square | df | Asymp. Sig. |
|---|---|---|---|---|---|---|
| Built. Env. | Objective Measure and Land Use | Distance to downtown | Distance to Seattle downtown | 134.936 | 2 | 0.000 |
| | | Number of each destination within a 1km network buffer | Church | 52.912 | 2 | 0.000 |
| | | | Grocery store | 59.294 | 2 | 0.000 |
| | | | Mixed use | 50.300 | 2 | 0.000 |
| | | Distance to the closest each destination within a 3km network buffer | Church | 16.057 | 2 | 0.000 |
| | | | Neighborhood/ community shopping center | 45.825 | 2 | 0.000 |
| | | | Grocery store | 30.691 | 2 | 0.000 |
| | | | Library | 27.873 | 2 | 0.000 |
| | | | Museum | 64.603 | 2 | 0.000 |
| | | | School | 26.164 | 2 | 0.000 |
| | Objective Measure & Infrastructure | Street length | Total street length | 116.856 | 2 | 0.000 |
| | | Sign | Number of traffic signs | 33.684 | 2 | 0.000 |
| | | Sidewalk length | Total sidewalk length | 57.181 | 2 | 0.000 |
| | | Intersection | Number of intersections | 113.866 | 2 | 0.000 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | 10.864 | 2 | 0.004 |

Table 2.9. ANOVA

| | Section | Variable/Measurements | | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|---|---|
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Between Groups | 57184486803.985 | 2 | 28592243401.992 | 146.925 | .000 |
| | | | | Within Groups | 95355904525.280 | 490 | 194603886.786 | | |
| | | | | Total | 152540391329.265 | 492 | | | |
| | | Number of each destination within a 1km network buffer | Church | Between Groups | 117.056 | 2 | 58.528 | 26.716 | .000 |
| | | | | Within Groups | 1073.463 | 490 | 2.191 | | |
| | | | | Total | 1190.519 | 492 | | | |
| | | | Grocery store | Between Groups | 193.646 | 2 | 96.823 | 30.187 | .000 |
| | | | | Within Groups | 1571.661 | 490 | 3.207 | | |
| | | | | Total | 1765.306 | 492 | | | |
| | | | Mixed use | Between Groups | 24.806 | 2 | 12.403 | 22.643 | .000 |
| | | | | Within Groups | 268.403 | 490 | .548 | | |
| | | | | Total | 293.209 | 492 | | | |
| | | Distance to the closest each destination within a 3km network buffer | Church | Between Groups | 7.329 | 2 | 3.665 | 6.904 | .001 |
| | | | | Within Groups | 260.104 | 490 | .531 | | |
| | | | | Total | 267.434 | 492 | | | |
| | | | Neighborhood/ community shopping center | Between Groups | 177.524 | 2 | 88.762 | 27.140 | .000 |
| | | | | Within Groups | 1602.581 | 490 | 3.271 | | |
| | | | | Total | 1780.105 | 492 | | | |
| | | | Grocery store | Between Groups | 12.575 | 2 | 6.287 | 14.250 | .000 |
| | | | | Within Groups | 216.194 | 490 | .441 | | |
| | | | | Total | 228.768 | 492 | | | |
| | | | Library | Between Groups | 105.108 | 2 | 52.554 | 20.353 | .000 |
| | | | | Within Groups | 1265.233 | 490 | 2.582 | | |
| | | | | Total | 1370.341 | 492 | | | |

Table 2.9. (Continued)

| | Section | Variable/Measurements | | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Museum | Between Groups | 129.368 | 2 | 64.684 | 36.349 | .000 |
| | | | | Within Groups | 871.975 | 490 | 1.780 | | |
| | | | | Total | 1001.343 | 492 | | | |
| | | | School | Between Groups | 10.247 | 2 | 5.124 | 12.770 | .000 |
| | | | | Within Groups | 196.607 | 490 | .401 | | |
| | | | | Total | 206.855 | 492 | | | |
| | Objective Measure & Infrastructure | Street length | Total street length | Between Groups | 122289469402.957 | 2 | 61144734701.479 | 76.126 | .000 |
| | | | | Within Groups | 393570868889.492 | 490 | 803205854.877 | | |
| | | | | Total | 515860338292.449 | 492 | | | |
| | | Sign | Number of traffic signs | Between Groups | 37.607 | 2 | 18.803 | 17.594 | .000 |
| | | | | Within Groups | 523.695 | 490 | 1.069 | | |
| | | | | Total | 561.302 | 492 | | | |
| | | Sidewalk length | Total sidewalk length | Between Groups | 13857595261.200 | 2 | 6928797630.600 | 34.675 | .000 |
| | | | | Within Groups | 97910985291.667 | 490 | 199818337.330 | | |
| | | | | Total | 111768580552.867 | 492 | | | |
| | | Intersection | Number of intersections | Between Groups | 323348.423 | 2 | 161674.212 | 69.393 | .000 |
| | | | | Within Groups | 1141610.956 | 490 | 2329.818 | | |
| | | | | Total | 1464959.379 | 492 | | | |
| Personal Factor | Demographics/ Individual Characteristics | Education | Education | Between Groups | 8.131 | 2 | 4.066 | 4.577 | .011 |
| | | | | Within Groups | 435.240 | 490 | .888 | | |
| | | | | Total | 443.371 | 492 | | | |

Table 2.10. Homogeneous Subsets

| | Section | Variable/Measurements | | | N | Subset for alpha = .05 | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 2 | 3 |
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Cold spot | 307 | 20913.02518737 | | |
| | | | | Not sig. | 99 | 22994.95364524 | | |
| | | | | Hot spot | 87 | | 49591.81933195 | |
| | | | | Sig. | | .247 | 1.000 | |
| | | Number of each destination within a 1km network buffer | Church | Hot spot | 87 | .42 | | |
| | | | | Cold spot | 307 | | .47 | |
| | | | | Not sig. | 99 | | .48 | |
| | | | | Sig. | | 1.000 | .550 | |
| | | | Grocery store | Hot spot | 87 | 11.02 | | |
| | | | | Cold spot | 99 | | 12.01 | |
| | | | | Not sig. | 307 | | | 12.68 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Mixed use | Hot spot | 87 | 10.75 | | |
| | | | | Cold spot | 99 | | 11.20 | |
| | | | | Not sig. | 307 | | 11.35 | |
| | | | | Sig. | | 1.000 | .117 | |
| | | Distance to the closest each destination within a 3km network buffer | Church | Not sig. | 307 | 7.21 | | |
| | | | | Cold spot | 99 | 7.30 | | |
| | | | | Hot spot | 87 | | 7.54 | |
| | | | | Sig. | | .357 | 1.000 | |
| | | | Neighborhood/ community shopping center | Hot spot | 87 | 12.37 | | |
| | | | | Cold spot | 99 | | 13.90 | |
| | | | | Not sig. | 307 | | 13.95 | |
| | | | | Sig. | | 1.000 | .812 | |
| | | | Grocery store | Not sig. | 307 | 7.55 | | |
| | | | | Cold spot | 99 | 7.64 | | |
| | | | | Hot spot | 87 | | 7.98 | |
| | | | | Sig. | | .300 | 1.000 | |
| | | | Library | Not sig. | 307 | 12.5505 | | |
| | | | | Cold spot | 99 | 12.8990 | | |
| | | | | Hot spot | 87 | | 13.7931 | |
| | | | | Sig. | | .093 | 1.000 | |
| | | | Museum | Not sig. | 307 | 11.6808 | | |
| | | | | Cold spot | 99 | 11.8788 | | |
| | | | | Hot spot | 87 | | 13.0575 | |
| | | | | Sig. | | .249 | 1.000 | |
| | | | School | Not sig. | 307 | 7.45 | | |
| | | | | Cold spot | 99 | 7.51 | | |
| | | | | Hot spot | 87 | | 7.84 | |
| | | | | Sig. | | .434 | 1.000 | |

Table 2.10. (Continued)

| | Section | Variable/Measurements | | | N | Subset for alpha = .05 | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 2 | 3 |
| | Objective Measure & Infrastructure | Street length | Total street length | Hot spot | 87 | 68596.14 | | |
| | | | | Cold spot | 99 | | 93027.23 | |
| | | | | Not sig. | 307 | | | 110186.12 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | Sign | Number of traffic signs | Hot spot | 87 | 1.42 | | |
| | | | | Cold spot | 99 | | 1.72 | |
| | | | | Not sig. | 307 | | | 2.11 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | Sidewalk length | Total sidewalk length | Hot spot | 87 | 25302.88 | | |
| | | | | Cold spot | 99 | | 35664.79 | |
| | | | | Not sig. | 307 | | | 39576.87 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | Intersection | Number of intersections | Hot spot | 87 | 88.22 | | |
| | | | | Cold spot | 99 | | 129.04 | |
| | | | | Not sig. | 307 | | | 156.05 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | Hot spot | 87 | 5.45 | | |
| | | | | Not sig. | 307 | | 5.76 | |
| | | | | Cold spot | 99 | | 5.83 | |
| | | | | Sig. | | 1.000 | .586 | |

## 2.3. Health Status Disparity: 3km Distance Spatial Weight

Table 2.11. Descriptive Statistics

| | Section | Variable/Measurements | | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Lower Bound | Upper Bound | | |
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Not sig. | 160 | 22222.52 | 9996.28 | 790.28 | 20661.73 | 23783.32 | 490.53 | 49212.45 |
| | | | | Hot spot | 105 | 46688.41 | 23525.38 | 2295.84 | 42135.67 | 51241.15 | 12616.18 | 118740.06 |
| | | | | Cold spot | 204 | 19919.27 | 10204.21 | 714.44 | 18510.59 | 21327.94 | 3352.26 | 50030.52 |
| | | | | Total | 469 | 26698.12 | 17850.43 | 824.26 | 25078.42 | 28317.82 | 490.53 | 118740.06 |
| | | Number of each destination within a 1km network buffer | Church | Not sig. | 160 | 11.99 | 1.04 | .08 | 11.83 | 12.15 | 10.00 | 16.00 |
| | | | | Hot spot | 105 | 11.13 | .76 | .07 | 10.99 | 11.28 | 10.00 | 13.00 |
| | | | | Cold spot | 204 | 12.54 | 1.83 | .13 | 12.29 | 12.79 | 10.00 | 17.00 |
| | | | | Total | 469 | 12.04 | 1.50 | .07 | 11.90 | 12.17 | 10.00 | 17.00 |
| | | | Grocery store | Not sig. | 160 | 12.33 | 1.85 | .15 | 12.04 | 12.62 | 10.00 | 16.00 |
| | | | | Hot spot | 105 | 10.91 | 1.20 | .12 | 10.68 | 11.15 | 10.00 | 16.00 |
| | | | | Cold spot | 204 | 12.84 | 1.94 | .14 | 12.57 | 13.11 | 10.00 | 16.00 |
| | | | | Total | 469 | 12.23 | 1.92 | .09 | 12.06 | 12.41 | 10.00 | 16.00 |
| | | | Mixed use | Not sig. | 160 | 11.31 | .67 | .05 | 11.21 | 11.42 | 10.00 | 13.00 |
| | | | | Hot spot | 105 | 10.79 | .58 | .06 | 10.68 | 10.90 | 10.00 | 12.00 |
| | | | | Cold spot | 204 | 11.36 | .88 | .06 | 11.24 | 11.48 | 10.00 | 14.00 |
| | | | | Total | 469 | 11.22 | .79 | .04 | 11.15 | 11.29 | 10.00 | 14.00 |
| | | Distance to the closest each destination within a 3km network buffer | Church | Not sig. | 160 | 7.22 | .65 | .05 | 7.12 | 7.32 | 4.26 | 8.90 |
| | | | | Hot spot | 105 | 7.54 | .74 | .07 | 7.39 | 7.68 | 5.15 | 9.18 |
| | | | | Cold spot | 204 | 7.24 | .78 | .05 | 7.13 | 7.34 | 4.31 | 9.03 |
| | | | | Total | 469 | 7.30 | .74 | .03 | 7.23 | 7.37 | 4.26 | 9.18 |
| | | | Neighborhood/ community shopping center | Not sig. | 160 | 13.84 | 1.97 | .16 | 13.53 | 14.15 | 10.00 | 16.00 |
| | | | | Hot spot | 105 | 12.60 | 1.83 | .18 | 12.25 | 12.95 | 10.00 | 16.00 |
| | | | | Cold spot | 204 | 14.07 | 1.72 | .12 | 13.83 | 14.31 | 10.00 | 16.00 |
| | | | | Total | 469 | 13.66 | 1.92 | .09 | 13.49 | 13.84 | 10.00 | 16.00 |
| | | | Grocery store | Not sig. | 160 | 7.63 | .62 | .05 | 7.54 | 7.73 | 5.25 | 8.74 |
| | | | | Hot spot | 105 | 8.02 | .75 | .07 | 7.87 | 8.16 | 4.80 | 9.19 |
| | | | | Cold spot | 204 | 7.47 | .64 | .04 | 7.38 | 7.56 | 4.44 | 8.89 |
| | | | | Total | 469 | 7.65 | .69 | .03 | 7.59 | 7.71 | 4.44 | 9.19 |
| | | | Library | Not sig. | 160 | 12.56 | 1.64 | .13 | 12.30 | 12.81 | 10.00 | 16.00 |
| | | | | Hot spot | 105 | 13.94 | 1.90 | .18 | 13.58 | 14.31 | 10.00 | 16.00 |
| | | | | Cold spot | 204 | 12.51 | 1.36 | .10 | 12.32 | 12.70 | 10.00 | 16.00 |
| | | | | Total | 469 | 12.85 | 1.69 | .08 | 12.69 | 13.00 | 10.00 | 16.00 |
| | | | Museum | Not sig. | 160 | 11.94 | 1.38 | .11 | 11.73 | 12.16 | 10.00 | 14.00 |
| | | | | Hot spot | 105 | 13.21 | 1.29 | .13 | 12.96 | 13.46 | 10.00 | 14.00 |
| | | | | Cold spot | 204 | 11.35 | 1.10 | .08 | 11.20 | 11.51 | 10.00 | 14.00 |
| | | | | Total | 469 | 11.97 | 1.43 | .07 | 11.84 | 12.10 | 10.00 | 14.00 |
| | | | School | Not sig. | 160 | 7.55 | .59 | .05 | 7.46 | 7.64 | 4.74 | 8.97 |
| | | | | Hot spot | 105 | 7.82 | .68 | .07 | 7.69 | 7.96 | 5.24 | 9.18 |
| | | | | Cold spot | 204 | 7.39 | .64 | .04 | 7.30 | 7.48 | 4.22 | 8.72 |
| | | | | Total | 469 | 7.54 | .65 | .03 | 7.48 | 7.60 | 4.22 | 9.18 |
| | Objective Measure & Infrastructure | Street length | Total street length | Not sig. | 160 | 105641.62 | 28685.72 | 2267.81 | 101162.72 | 110120.53 | 17988.50 | 197338.90 |
| | | | | Hot spot | 105 | 71358.45 | 25098.43 | 2449.36 | 66501.29 | 76215.62 | 14972.10 | 128223.50 |
| | | | | Cold spot | 204 | 106355.79 | 30887.73 | 2162.57 | 102091.80 | 110619.78 | 23569.40 | 188471.90 |
| | | | | Total | 469 | 98276.93 | 32294.65 | 1491.23 | 95346.59 | 101207.26 | 14972.10 | 197338.90 |
| | | Sign | Number of traffic signs | Not sig. | 160 | 2.03 | 1.19 | .09 | 1.84 | 2.22 | .00 | 4.85 |
| | | | | Hot spot | 105 | 1.37 | .78 | .08 | 1.22 | 1.52 | .00 | 3.53 |
| | | | | Cold spot | 204 | 2.03 | 1.01 | .07 | 1.89 | 2.17 | .00 | 4.44 |
| | | | | Total | 469 | 1.88 | 1.07 | .05 | 1.79 | 1.98 | .00 | 4.85 |
| | | Sidewalk length | Total sidewalk length | Not sig. | 160 | 38411.81 | 12495.87 | 987.89 | 36460.74 | 40362.88 | 3983.30 | 76162.20 |
| | | | | Hot spot | 105 | 25466.87 | 13075.72 | 1276.06 | 22936.39 | 27997.34 | 325.10 | 56435.40 |
| | | | | Cold spot | 204 | 39663.03 | 15251.62 | 1067.83 | 37557.58 | 41768.49 | 9143.50 | 83974.80 |
| | | | | Total | 469 | 36057.93 | 14988.93 | 692.12 | 34697.87 | 37417.99 | 325.10 | 83974.80 |
| | | Intersection | Number of intersections | Not sig. | 160 | 146.37 | 46.66 | 3.69 | 139.08 | 153.65 | 15.00 | 265.00 |
| | | | | Hot spot | 105 | 88.89 | 34.49 | 3.37 | 82.21 | 95.56 | 14.00 | 167.00 |
| | | | | Cold spot | 204 | 154.16 | 54.87 | 3.84 | 146.59 | 161.74 | 11.00 | 269.00 |
| | | | | Total | 469 | 136.89 | 54.66 | 2.52 | 131.93 | 141.85 | 11.00 | 269.00 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | Not sig. | 160 | 5.83 | .89 | .07 | 5.69 | 5.96 | 3.00 | 7.00 |
| | | | | Hot spot | 105 | 5.48 | .97 | .09 | 5.29 | 5.66 | 3.00 | 7.00 |
| | | | | Cold spot | 204 | 5.79 | .92 | .06 | 5.67 | 5.92 | 3.00 | 7.00 |
| | | | | Total | 469 | 5.73 | .93 | .04 | 5.65 | 5.82 | 3.00 | 7.00 |

## Table 2.12. Test of Homogeneity of Variances

| | Section | Variable/Measurement | | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|---|---|---|
| Built. Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | 23.968 | 2 | 466 | .000 |
| | | Number of each destination within a 1km network buffer | Church | 49.619 | 2 | 466 | .000 |
| | | | Grocery store | 25.302 | 2 | 466 | .000 |
| | | | Mixed use | 11.920 | 2 | 466 | .000 |
| | | Distance to the closest each destination within a 3km network buffer | Church | 3.899 | 2 | 466 | .021 |
| | | | Neighborhood/ community shopping center | 3.946 | 2 | 466 | .020 |
| | | | Grocery store | 1.738 | 2 | 466 | .177 |
| | | | Library | 18.132 | 2 | 466 | .000 |
| | | | Museum | 8.970 | 2 | 466 | .000 |
| | | | School | 2.396 | 2 | 466 | .092 |
| | Objective Measure & Infrastructure | Street length | Total street length | 3.184 | 2 | 466 | .042 |
| | | Sign | Number of traffic signs | 5.545 | 2 | 466 | .004 |
| | | Sidewalk length | Total sidewalk length | 4.474 | 2 | 466 | .012 |
| | | Intersection | Number of intersections | 11.674 | 2 | 466 | .000 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | 2.336 | 2 | 466 | .098 |

## Table 2.13. Kruskal Wallis Test

| | Section | Variable/Measurements | | Chi-Square | df | Asymp. Sig. |
|---|---|---|---|---|---|---|
| Built. Env. | Objective Measure and Land Use | Distance to downtown | Distance to Seattle downtown | 151.374 | 2 | 0.000 |
| | | Number of each destination within a 1km network buffer | Church | 66.774 | 2 | 0.000 |
| | | | Grocery store | 80.963 | 2 | 0.000 |
| | | | Mixed use | 41.529 | 2 | 0.000 |
| | | Distance to the closest each destination within a 3km network buffer | Church | 15.150 | 2 | 0.001 |
| | | | Neighborhood/ community shopping center | 40.339 | 2 | 0.000 |
| | | | Grocery store | 50.651 | 2 | 0.000 |
| | | | Library | 44.881 | 2 | 0.000 |
| | | | Museum | 116.938 | 2 | 0.000 |
| | | | School | 32.181 | 2 | 0.000 |
| | Objective Measure & Infrastructure | Street length | Total street length | 100.426 | 2 | 0.000 |
| | | Sign | Number of traffic signs | 43.239 | 2 | 0.000 |
| | | Sidewalk length | Total sidewalk length | 65.729 | 2 | 0.000 |
| | | Intersection | Number of intersections | 118.805 | 2 | 0.000 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | 10.428 | 2 | 0.005 |

## Table 2.14. ANOVA

| | Section | Variable/Measurements | | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|---|---|
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Between Groups | 54538554310.028 | 2 | 27269277155.014 | 134.351 | .000 |
| | | | | Within Groups | 94583881857.512 | 466 | 202969703.557 | | |
| | | | | Total | 149122436167.541 | 468 | | | |
| | | Number of each destination within a 1km network buffer | Church | Between Groups | 137.589 | 2 | 68.795 | 35.121 | .000 |
| | | | | Within Groups | 912.795 | 466 | 1.959 | | |
| | | | | Total | 1050.384 | 468 | | | |
| | | | Grocery store | Between Groups | 258.866 | 2 | 129.433 | 41.331 | .000 |
| | | | | Within Groups | 1459.334 | 466 | 3.132 | | |
| | | | | Total | 1718.200 | 468 | | | |
| | | | Mixed use | Between Groups | 24.894 | 2 | 12.447 | 21.895 | .000 |
| | | | | Within Groups | 264.922 | 466 | .569 | | |
| | | | | Total | 289.817 | 468 | | | |
| | | Distance to the closest each destination within a 3km network buffer | Church | Between Groups | 7.686 | 2 | 3.843 | 7.218 | .001 |
| | | | | Within Groups | 248.100 | 466 | .532 | | |
| | | | | Total | 255.786 | 468 | | | |
| | | | Neighborhood/ community shopping center | Between Groups | 157.082 | 2 | 78.541 | 23.371 | .000 |
| | | | | Within Groups | 1566.014 | 466 | 3.361 | | |
| | | | | Total | 1723.096 | 468 | | | |
| | | | Grocery store | Between Groups | 20.555 | 2 | 10.278 | 23.601 | .000 |
| | | | | Within Groups | 202.934 | 466 | .435 | | |
| | | | | Total | 223.489 | 468 | | | |
| | | | Library | Between Groups | 162.815 | 2 | 81.408 | 32.200 | .000 |
| | | | | Within Groups | 1178.131 | 466 | 2.528 | | |
| | | | | Total | 1340.947 | 468 | | | |

Table 2.14. (Continued)

| | Section | Variable/Measurements | | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Museum | Between Groups | 239.110 | 2 | 119.555 | 77.114 | .000 |
| | | | | Within Groups | 722.472 | 466 | 1.550 | | |
| | | | | Total | 961.582 | 468 | | | |
| | | | School | Between Groups | 13.287 | 2 | 6.643 | 16.526 | .000 |
| | | | | Within Groups | 187.332 | 466 | .402 | | |
| | | | | Total | 200.619 | 468 | | | |
| | Objective Measure & Infrastructure | Street length | Total street length | Between Groups | 98076325131.802 | 2 | 49038162565.901 | 58.591 | .000 |
| | | | | Within Groups | 390021798390.081 | 466 | 836956648.906 | | |
| | | | | Total | 488098123521.883 | 468 | | | |
| | | Sign | Number of traffic signs | Between Groups | 35.197 | 2 | 17.599 | 16.479 | .000 |
| | | | | Within Groups | 497.665 | 466 | 1.068 | | |
| | | | | Total | 532.862 | 468 | | | |
| | | Sidewalk length | Total sidewalk length | Between Groups | 15315780153.944 | 2 | 7657890076.972 | 39.726 | .000 |
| | | | | Within Groups | 89828874267.017 | 466 | 192765824.607 | | |
| | | | | Total | 105144654420.962 | 468 | | | |
| | | Intersection | Number of intersections | Between Groups | 317194.700 | 2 | 158597.350 | 68.360 | .000 |
| | | | | Within Groups | 1081135.534 | 466 | 2320.033 | | |
| | | | | Total | 1398330.235 | 468 | | | |
| Personal Factor | Demographics/ Individual Characteristics | Education | Education | Between Groups | 9.041 | 2 | 4.521 | 5.311 | .005 |
| | | | | Within Groups | 396.643 | 466 | .851 | | |
| | | | | Total | 405.684 | 468 | | | |

Table 2.15. Homogeneous Subsets

| | Section | Variable/Measurements | | | N | Subset for alpha = .05 | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 2 | 3 |
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Cold spot | 204 | 19919.26549758 | | |
| | | | | Not sig. | 160 | 22222.52463218 | | |
| | | | | Hot spot | 105 | | 46688.40729400 | |
| | | | | Sig. | | .169 | 1.000 | |
| | | Number of each destination within a 1km network buffer | Church | Hot spot | 105 | 11.13 | | |
| | | | | Cold spot | 160 | | 11.99 | |
| | | | | Not sig. | 204 | | | 12.54 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Grocery store | Hot spot | 105 | 10.91 | | |
| | | | | Cold spot | 160 | | 12.33 | |
| | | | | Not sig. | 204 | | | 12.84 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Mixed use | Hot spot | 105 | 10.79 | | |
| | | | | Cold spot | 160 | | 11.31 | |
| | | | | Not sig. | 204 | | 11.36 | |
| | | | | Sig. | | 1.000 | .571 | |
| | | Distance to the closest each destination within a 3km network buffer | Church | Not sig. | 160 | 7.22 | | |
| | | | | Cold spot | 204 | 7.24 | | |
| | | | | Hot spot | 105 | | 7.54 | |
| | | | | Sig. | | .859 | 1.000 | |
| | | | Neighborhood/ community shopping center | Hot spot | 105 | 12.60 | | |
| | | | | Cold spot | 160 | | 13.84 | |
| | | | | Not sig. | 204 | | 14.07 | |
| | | | | Sig. | | 1.000 | .283 | |
| | | | Grocery store | Not sig. | 204 | 7.47 | | |
| | | | | Cold spot | 160 | | 7.63 | |
| | | | | Hot spot | 105 | | | 8.02 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Library | Not sig. | 204 | 12.51 | | |
| | | | | Cold spot | 160 | 12.56 | | |
| | | | | Hot spot | 105 | | 13.94 | |
| | | | | Sig. | | .804 | 1.000 | |
| | | | Museum | Not sig. | 204 | 11.35 | | |
| | | | | Cold spot | 160 | | 11.94 | |
| | | | | Hot spot | 105 | | | 13.21 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | School | Not sig. | 204 | 7.39 | | |
| | | | | Cold spot | 160 | | 7.55 | |
| | | | | Hot spot | 105 | | | 7.82 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |

Table 2.15. (Continued)

| | Section | Variable/Measurements | | | N | Subset for alpha = .05 | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 2 | 3 |
| | Objective Measure & Infrastructure | Street length | Total street length | Hot spot | 105 | 71358.45 | | |
| | | | | Cold spot | 160 | | 105641.62 | |
| | | | | Not sig. | 204 | | 106355.79 | |
| | | | | Sig. | | 1.000 | .834 | |
| | | Sign | Number of traffic signs | Hot spot | 105 | 1.37 | | |
| | | | | Cold spot | 204 | | 2.03 | |
| | | | | Not sig. | 160 | | 2.03 | |
| | | | | Sig. | | 1.000 | .993 | |
| | | Sidewalk length | Total sidewalk length | Hot spot | 105 | 25466.866 | | |
| | | | | Cold spot | 160 | | 38411.812 | |
| | | | | Not sig. | 204 | | 39663.033 | |
| | | | | Sig. | | 1.000 | .443 | |
| | | Intersection | Number of intersections | Hot spot | 105 | 88.89 | | |
| | | | | Cold spot | 160 | | 146.37 | |
| | | | | Not sig. | 204 | | 154.16 | |
| | | | | Sig. | | 1.000 | .169 | |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | Hot spot | 105 | 5.48 | | |
| | | | | Not sig. | 204 | | 5.79 | |
| | | | | Cold spot | 160 | | 5.83 | |
| | | | | Sig. | | 1.000 | .776 | |

## 2.4. BMI Disparity: 4-nearest Neighbors Spatial Weight

Table 2.16. Descriptive Statistics

| | Section | Variable/Measurements | | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Lower Bound | Upper Bound | | |
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to downtown | Not sig. | 330 | 23331.31 | 15547.52 | 855.86 | 21647.66 | 25014.96 | 490.53 | 69188.83 |
| | | | | Hot spot | 66 | 38961.64 | 28144.57 | 3464.36 | 32042.84 | 45880.43 | 20418.05 | 118740.06 |
| | | | | Cold spot | 107 | 29586.86 | 9781.04 | 945.57 | 27712.18 | 31461.54 | 14966.98 | 67475.06 |
| | | | | Total | 503 | 26712.91 | 17612.23 | 785.29 | 25170.05 | 28255.77 | 490.53 | 118740.06 |
| | | Number of each destination within a 1km network buffer | Church | Not sig. | 330 | 12.14 | 1.71 | .09 | 11.96 | 12.33 | 10.00 | 17.00 |
| | | | | Hot spot | 66 | 11.59 | .98 | .12 | 11.35 | 11.83 | 10.00 | 15.00 |
| | | | | Cold spot | 107 | 12.25 | 1.27 | .12 | 12.01 | 12.50 | 10.00 | 15.00 |
| | | | | Total | 503 | 12.09 | 1.56 | .07 | 11.96 | 12.23 | 10.00 | 17.00 |
| | | | Museum | Not sig. | 330 | 10.25 | .44 | .02 | 10.21 | 10.30 | 10.00 | 11.00 |
| | | | | Hot spot | 66 | 10.11 | .31 | .04 | 10.03 | 10.18 | 10.00 | 11.00 |
| | | | | Cold spot | 107 | 10.36 | .48 | .05 | 10.26 | 10.45 | 10.00 | 11.00 |
| | | | | Total | 503 | 10.26 | .44 | .02 | 10.22 | 10.29 | 10.00 | 11.00 |
| | | | Office | Not sig. | 330 | 12.33 | 1.32 | .07 | 12.19 | 12.47 | 10.00 | 14.00 |
| | | | | Hot spot | 66 | 11.48 | .88 | .11 | 11.27 | 11.70 | 10.00 | 14.00 |
| | | | | Cold spot | 107 | 11.93 | 1.08 | .10 | 11.72 | 12.13 | 10.00 | 14.00 |
| | | | | Total | 503 | 12.13 | 1.26 | .06 | 12.02 | 12.24 | 10.00 | 14.00 |
| | | | Regional shopping center | Not sig. | 330 | 10.01 | .10 | .01 | 10.00 | 10.02 | 10.00 | 11.00 |
| | | | | Hot spot | 66 | 10.11 | .31 | .04 | 10.03 | 10.18 | 10.00 | 11.00 |
| | | | | Cold spot | 107 | 10.00 | .00 | .00 | 10.00 | 10.00 | 10.00 | 10.00 |
| | | | | Total | 503 | 10.02 | .14 | .01 | 10.01 | 10.03 | 10.00 | 11.00 |
| | | | Retail store | Not sig. | 330 | 12.39 | 1.52 | .08 | 12.23 | 12.56 | 10.00 | 15.00 |
| | | | | Hot spot | 66 | 11.77 | 1.12 | .14 | 11.50 | 12.05 | 11.00 | 15.00 |
| | | | | Cold spot | 107 | 12.39 | 1.42 | .14 | 12.12 | 12.66 | 10.00 | 15.00 |
| | | | | Total | 503 | 12.31 | 1.47 | .07 | 12.18 | 12.44 | 10.00 | 15.00 |
| | | | Theater | Not sig. | 330 | 10.38 | .49 | .03 | 10.33 | 10.43 | 10.00 | 11.00 |
| | | | | Hot spot | 66 | 10.09 | .29 | .04 | 10.02 | 10.16 | 10.00 | 11.00 |
| | | | | Cold spot | 107 | 10.36 | .48 | .05 | 10.26 | 10.45 | 10.00 | 11.00 |
| | | | | Total | 503 | 10.34 | .47 | .02 | 10.29 | 10.38 | 10.00 | 11.00 |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | Not sig. | 330 | 13.48 | 1.85 | .10 | 13.28 | 13.68 | 10.00 | 16.00 |
| | | | | Hot spot | 66 | 13.32 | 1.84 | .23 | 12.87 | 13.77 | 10.00 | 16.00 |
| | | | | Cold spot | 107 | 14.32 | 1.93 | .19 | 13.95 | 14.69 | 10.00 | 16.00 |
| | | | | Total | 503 | 13.63 | 1.90 | .08 | 13.47 | 13.80 | 10.00 | 16.00 |
| | | | Museum | Not sig. | 330 | 11.98 | 1.43 | .08 | 11.83 | 12.14 | 10.00 | 14.00 |
| | | | | Hot spot | 66 | 12.62 | 1.31 | .16 | 12.30 | 12.94 | 10.00 | 14.00 |
| | | | | Cold spot | 107 | 11.60 | 1.39 | .13 | 11.33 | 11.87 | 10.00 | 14.00 |
| | | | | Total | 503 | 11.98 | 1.43 | .06 | 11.86 | 12.11 | 10.00 | 14.00 |
| | | | Regional shopping center | Not sig. | 330 | 10.87 | .34 | .02 | 10.83 | 10.90 | 10.00 | 11.00 |
| | | | | Hot spot | 66 | 10.39 | .49 | .06 | 10.27 | 10.51 | 10.00 | 11.00 |
| | | | | Cold spot | 107 | 10.94 | .23 | .02 | 10.90 | 10.99 | 10.00 | 11.00 |
| | | | | Total | 503 | 10.82 | .38 | .02 | 10.79 | 10.85 | 10.00 | 11.00 |
| | | | Theater | Not sig. | 330 | 11.27 | 1.14 | .06 | 11.14 | 11.39 | 10.00 | 13.00 |
| | | | | Hot spot | 66 | 11.91 | .97 | .12 | 11.67 | 12.15 | 10.00 | 13.00 |
| | | | | Cold spot | 107 | 11.07 | .94 | .09 | 10.89 | 11.25 | 10.00 | 13.00 |
| | | | | Total | 503 | 11.31 | 1.10 | .05 | 11.21 | 11.41 | 10.00 | 13.00 |
| Personal Factor | Demographics/Individual Characteristics | Income | Income | Not sig. | 330 | 6.40 | 1.43 | .08 | 6.25 | 6.56 | 4.00 | 8.00 |
| | | | | Hot spot | 66 | 5.91 | 1.50 | .18 | 5.54 | 6.28 | 4.00 | 8.00 |
| | | | | Cold spot | 107 | 6.60 | 1.35 | .13 | 6.34 | 6.86 | 4.00 | 8.00 |
| | | | | Total | 503 | 6.38 | 1.44 | .06 | 6.25 | 6.51 | 4.00 | 8.00 |

Table 2.17. Test of Homogeneity of Variances

| | Section | Variable/Measurements | | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|---|---|---|
| Built. Env. | Objective Measure and Land Use | Distance to downtown | Distance to Seattle downtown | 24.413 | 2 | 500 | .000 |
| | | Number of each destination within a 1km network buffer | Church | 5.781 | 2 | 500 | .003 |
| | | | Museum | 35.726 | 2 | 500 | .000 |
| | | | Office | 27.416 | 2 | 500 | .000 |
| | | | Regional shopping center | 66.769 | 2 | 500 | .000 |
| | | | Retail store | 13.397 | 2 | 500 | .000 |
| | | | Theater | 127.799 | 2 | 500 | .000 |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | .650 | 2 | 500 | .523 |
| | | | Museum | 1.150 | 2 | 500 | .318 |
| | | | Regional shopping center | 55.188 | 2 | 500 | .000 |
| | | | Theater | 13.152 | 2 | 500 | .000 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | 1.309 | 2 | 500 | .271 |

## Table 2.18. Kruskal Wallis Test

| | Section | Variable/Measurements | | Chi-Square | df | Asymp. Sig. |
|---|---|---|---|---|---|---|
| Built. Env. | Objective Measure and Land Use | Distance to downtown | Distance to Seattle downtown | 47.398 | 2 | 0.000 |
| | | Number of each destination within a 1km network buffer | Church | 13.169 | 2 | 0.001 |
| | | | Museum | 13.273 | 2 | 0.001 |
| | | | Office | 25.923 | 2 | 0.000 |
| | | | Regional shopping center | 29.240 | 2 | 0.000 |
| | | | Retail store | 9.731 | 2 | 0.008 |
| | | | Theater | 20.613 | 2 | 0.000 |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | 18.313 | 2 | 0.000 |
| | | | Museum | 20.964 | 2 | 0.000 |
| | | | Regional shopping center | 97.430 | 2 | 0.000 |
| | | | Theater | 25.013 | 2 | 0.000 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | 3.998 | 2 | 0.135 |

## Table 2.19. ANOVA

| | Section | Variable/Measurements | | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|---|---|
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Between Groups | 14559463107.057 | 2 | 7279731553.528 | 25.786 | .000 |
| | | | | Within Groups | 141156168823.287 | 500 | 282312337.647 | | |
| | | | | Total | 155715631930.344 | 502 | | | |
| | | Number of each destination within a 1km network buffer | Church | Between Groups | 20.161 | 2 | 10.080 | 4.220 | .015 |
| | | | | Within Groups | 1194.448 | 500 | 2.389 | | |
| | | | | Total | 1214.608 | 502 | | | |
| | | | Museum | Between Groups | 2.536 | 2 | 1.268 | 6.790 | .001 |
| | | | | Within Groups | 93.380 | 500 | .187 | | |
| | | | | Total | 95.917 | 502 | | | |
| | | | Office | Between Groups | 45.192 | 2 | 22.596 | 15.046 | .000 |
| | | | | Within Groups | 750.884 | 500 | 1.502 | | |
| | | | | Total | 796.076 | 502 | | | |
| | | | Regional shopping center | Between Groups | .571 | 2 | .285 | 15.462 | .000 |
| | | | | Within Groups | 9.230 | 500 | .018 | | |
| | | | | Total | 9.801 | 502 | | | |
| | | | Retail store | Between Groups | 22.103 | 2 | 11.052 | 5.223 | .006 |
| | | | | Within Groups | 1057.893 | 500 | 2.116 | | |
| | | | | Total | 1079.996 | 502 | | | |
| | | | Theater | Between Groups | 4.608 | 2 | 2.304 | 10.705 | .000 |
| | | | | Within Groups | 107.611 | 500 | .215 | | |
| | | | | Total | 112.219 | 502 | | | |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | Between Groups | 64.871 | 2 | 32.436 | 9.290 | .000 |
| | | | | Within Groups | 1745.821 | 500 | 3.492 | | |
| | | | | Total | 1810.692 | 502 | | | |
| | | | Museum | Between Groups | 42.732 | 2 | 21.366 | 10.800 | .000 |
| | | | | Within Groups | 989.141 | 500 | 1.978 | | |
| | | | | Total | 1031.873 | 502 | | | |
| | | | Regional shopping center | Between Groups | 14.342 | 2 | 7.171 | 60.206 | .000 |
| | | | | Within Groups | 59.554 | 500 | .119 | | |
| | | | | Total | 73.897 | 502 | | | |
| | | | Theater | Between Groups | 30.229 | 2 | 15.114 | 13.043 | .000 |
| | | | | Within Groups | 579.390 | 500 | 1.159 | | |
| | | | | Total | 609.618 | 502 | | | |
| Personal Factor | Demographics/ Individual Characteristics | Education | Education | Between Groups | 19.902 | 2 | 9.951 | 4.904 | .008 |
| | | | | Within Groups | 1014.571 | 500 | 2.029 | | |
| | | | | Total | 1034.473 | 502 | | | |

Table 2.20. Homogeneous Subsets

| | Section | Variable/Measurements | | | N | Subset for alpha = .05 | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 2 | 3 |
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Not sig. | 330 | 23331.30998985 | | |
| | | | | Cold spot | 107 | | 29586.86089196 | |
| | | | | Hot spot | 66 | | | 38961.63561742 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | Number of each destination within a 1km network buffer | Church | Hot spot | 66 | 11.59 | | |
| | | | | Not sig. | 330 | | 12.14 | |
| | | | | Cold spot | 107 | | 12.25 | |
| | | | | Sig. | | 1.000 | .600 | |
| | | | Museum | Hot spot | 66 | 10.11 | | |
| | | | | Not sig. | 330 | | 10.25 | |
| | | | | Cold spot | 107 | | 10.36 | |
| | | | | Sig. | | 1.000 | .086 | |
| | | | Office | Hot spot | 66 | 11.48 | | |
| | | | | Cold spot | 107 | | 11.93 | |
| | | | | Not sig. | 330 | | | 12.33 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Regional shopping center | Cold spot | 107 | 10.00 | | |
| | | | | Not sig. | 330 | 10.01 | | |
| | | | | Hot spot | 66 | | 10.11 | |
| | | | | Sig. | | .622 | 1.000 | |
| | | | Retail store | Hot spot | 66 | 11.77 | | |
| | | | | Cold spot | 107 | | 12.39 | |
| | | | | Not sig. | 330 | | 12.39 | |
| | | | | Sig. | | 1.000 | .994 | |
| | | | Theater | Hot spot | 66 | 10.09 | | |
| | | | | Cold spot | 107 | | 10.36 | |
| | | | | Not sig. | 330 | | 10.38 | |
| | | | | Sig. | | 1.000 | .707 | |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | Hot spot | 66 | 13.32 | | |
| | | | | Not sig. | 330 | 13.48 | | |
| | | | | Cold spot | 107 | | 14.32 | |
| | | | | Sig. | | .534 | 1.000 | |
| | | | Museum | Cold spot | 107 | 11.60 | | |
| | | | | Not sig. | 330 | | 11.98 | |
| | | | | Hot spot | 66 | | | 12.62 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Regional shopping center | Hot spot | 66 | 10.39 | | |
| | | | | Not sig. | 330 | | 10.87 | |
| | | | | Cold spot | 107 | | 10.94 | |
| | | | | Sig. | | 1.000 | .099 | |
| | | | Theater | Cold spot | 107 | 11.07 | | |
| | | | | Not sig. | 330 | 11.27 | | |
| | | | | Hot spot | 66 | | 11.91 | |
| | | | | Sig. | | .189 | 1.000 | |
| Personal Factor | Demographics/Individual Characteristics | Income | Income | Hot spot | 66 | 5.91 | | |
| | | | | Not sig. | 330 | | 6.40 | |
| | | | | Cold spot | 107 | | 6.60 | |
| | | | | Sig. | | 1.000 | .312 | |

## 2.5. BMI Disparity: 10-nearest Neighbors Spatial Weight

Table 2.21. Descriptive Statistics

| | Section | Variable/Measurements | | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Lower Bound | Upper Bound | | |
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to downtown | Not sig. | 251 | 20301.23 | 14820.18 | 935.44 | 18458.88 | 22143.58 | 490.53 | 57953.43 |
| | | | | Hot spot | 94 | 37218.00 | 24498.50 | 2526.83 | 32200.22 | 42235.78 | 19805.51 | 118740.06 |
| | | | | Cold spot | 156 | 30487.42 | 11781.67 | 943.29 | 28624.06 | 32350.78 | 12616.18 | 69188.83 |
| | | | | Total | 501 | 26646.98 | 17615.53 | 787.00 | 25100.74 | 28193.23 | 490.53 | 118740.06 |
| | | Number of each destination within a 1km network buffer | Church | Not sig. | 251 | 12.33 | 1.85 | .12 | 12.10 | 12.56 | 10.00 | 17.00 |
| | | | | Hot spot | 94 | 11.56 | .95 | .10 | 11.37 | 11.76 | 10.00 | 15.00 |
| | | | | Cold spot | 156 | 12.04 | 1.23 | .10 | 11.85 | 12.24 | 10.00 | 15.00 |
| | | | | Total | 501 | 12.10 | 1.56 | .07 | 11.96 | 12.23 | 10.00 | 17.00 |
| | | | Museum | Not sig. | 251 | 10.27 | .45 | .03 | 10.22 | 10.33 | 10.00 | 11.00 |
| | | | | Hot spot | 94 | 10.15 | .36 | .04 | 10.08 | 10.22 | 10.00 | 11.00 |
| | | | | Cold spot | 156 | 10.30 | .46 | .04 | 10.23 | 10.37 | 10.00 | 11.00 |
| | | | | Total | 501 | 10.26 | .44 | .02 | 10.22 | 10.30 | 10.00 | 11.00 |
| | | | Office | Not sig. | 251 | 12.51 | 1.33 | .08 | 12.34 | 12.67 | 10.00 | 14.00 |
| | | | | Hot spot | 94 | 11.59 | .93 | .10 | 11.39 | 11.78 | 10.00 | 14.00 |
| | | | | Cold spot | 156 | 11.88 | 1.13 | .09 | 11.70 | 12.06 | 10.00 | 14.00 |
| | | | | Total | 501 | 12.14 | 1.26 | .06 | 12.03 | 12.25 | 10.00 | 14.00 |
| | | | Regional shopping center | Not sig. | 251 | 10.01 | .11 | .01 | 10.00 | 10.03 | 10.00 | 11.00 |
| | | | | Hot spot | 94 | 10.07 | .26 | .03 | 10.02 | 10.13 | 10.00 | 11.00 |
| | | | | Cold spot | 156 | 10.00 | .00 | .00 | 10.00 | 10.00 | 10.00 | 10.00 |
| | | | | Total | 501 | 10.02 | .14 | .01 | 10.01 | 10.03 | 10.00 | 11.00 |
| | | | Retail store | Not sig. | 251 | 12.50 | 1.51 | .10 | 12.31 | 12.69 | 10.00 | 15.00 |
| | | | | Hot spot | 94 | 11.83 | 1.20 | .12 | 11.58 | 12.07 | 11.00 | 15.00 |
| | | | | Cold spot | 156 | 12.32 | 1.49 | .12 | 12.08 | 12.56 | 10.00 | 15.00 |
| | | | | Total | 501 | 12.32 | 1.47 | .07 | 12.19 | 12.45 | 10.00 | 15.00 |
| | | | Theater | Not sig. | 251 | 10.41 | .49 | .03 | 10.35 | 10.47 | 10.00 | 11.00 |
| | | | | Hot spot | 94 | 10.11 | .31 | .03 | 10.04 | 10.17 | 10.00 | 11.00 |
| | | | | Cold spot | 156 | 10.37 | .48 | .04 | 10.29 | 10.44 | 10.00 | 11.00 |
| | | | | Total | 501 | 10.34 | .47 | .02 | 10.30 | 10.38 | 10.00 | 11.00 |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | Not sig. | 251 | 13.49 | 1.79 | .11 | 13.26 | 13.71 | 10.00 | 16.00 |
| | | | | Hot spot | 94 | 13.29 | 1.86 | .19 | 12.91 | 13.67 | 10.00 | 16.00 |
| | | | | Cold spot | 156 | 14.10 | 2.01 | .16 | 13.79 | 14.42 | 10.00 | 16.00 |
| | | | | Total | 501 | 13.64 | 1.90 | .08 | 13.47 | 13.81 | 10.00 | 16.00 |
| | | | Museum | Not sig. | 251 | 11.95 | 1.44 | .09 | 11.77 | 12.13 | 10.00 | 14.00 |
| | | | | Hot spot | 94 | 12.38 | 1.37 | .14 | 12.10 | 12.66 | 10.00 | 14.00 |
| | | | | Cold spot | 156 | 11.78 | 1.42 | .11 | 11.55 | 12.00 | 10.00 | 14.00 |
| | | | | Total | 501 | 11.98 | 1.43 | .06 | 11.85 | 12.10 | 10.00 | 14.00 |
| | | | Regional shopping center | Not sig. | 251 | 10.89 | .32 | .02 | 10.85 | 10.93 | 10.00 | 11.00 |
| | | | | Hot spot | 94 | 10.44 | .50 | .05 | 10.33 | 10.54 | 10.00 | 11.00 |
| | | | | Cold spot | 156 | 10.94 | .23 | .02 | 10.91 | 10.98 | 10.00 | 11.00 |
| | | | | Total | 501 | 10.82 | .38 | .02 | 10.79 | 10.85 | 10.00 | 11.00 |
| | | | Theater | Not sig. | 251 | 11.19 | 1.14 | .07 | 11.05 | 11.33 | 10.00 | 13.00 |
| | | | | Hot spot | 94 | 11.95 | .97 | .10 | 11.75 | 12.14 | 10.00 | 13.00 |
| | | | | Cold spot | 156 | 11.11 | .98 | .08 | 10.95 | 11.26 | 10.00 | 13.00 |
| | | | | Total | 501 | 11.31 | 1.10 | .05 | 11.21 | 11.40 | 10.00 | 13.00 |
| Personal Factor | Demographics/Individual Characteristics | Income | Income | Not sig. | 251 | 6.27 | 1.48 | .09 | 6.09 | 6.46 | 4.00 | 8.00 |
| | | | | Hot spot | 94 | 6.10 | 1.50 | .15 | 5.79 | 6.40 | 4.00 | 8.00 |
| | | | | Cold spot | 156 | 6.72 | 1.28 | .10 | 6.52 | 6.93 | 4.00 | 8.00 |
| | | | | Total | 501 | 6.38 | 1.44 | .06 | 6.25 | 6.51 | 4.00 | 8.00 |

Table 2.22. Test of Homogeneity of Variances

| | Section | Variable/Measurements | | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|---|---|---|
| Built. Env. | Objective Measure and Land Use | Distance to downtown | Distance to Seattle downtown | 11.754 | 2 | 498 | .000 |
| | | Number of each destination within a 1km network buffer | Church | 17.304 | 2 | 498 | .000 |
| | | | Museum | 21.080 | 2 | 498 | .000 |
| | | | Office | 28.310 | 2 | 498 | .000 |
| | | | Regional shopping center | 40.222 | 2 | 498 | .000 |
| | | | Retail store | 14.095 | 2 | 498 | .000 |
| | | | Theater | 151.182 | 2 | 498 | .000 |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | 3.674 | 2 | 498 | .026 |
| | | | Museum | .481 | 2 | 498 | .619 |
| | | | Regional shopping center | 101.539 | 2 | 498 | .000 |
| | | | Theater | 6.889 | 2 | 498 | .001 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | 7.412 | 2 | 498 | .001 |

Table 2.23. Kruskal Wallis Test

| | Section | Variable/Measurements | | Chi-Square | df | Asymp. Sig. |
|---|---|---|---|---|---|---|
| Built. Env. | Objective Measure and Land Use | Distance to downtown | Distance to Seattle downtown | 96.589 | 2 | 0.000 |
| | | Number of each destination within a 1km network buffer | Church | 13.477 | 2 | 0.001 |
| | | | Museum | 7.580 | 2 | 0.023 |
| | | | Office | 40.950 | 2 | 0.000 |
| | | | Regional shopping center | 18.241 | 2 | 0.000 |
| | | | Retail store | 13.789 | 2 | 0.001 |
| | | | Theater | 28.274 | 2 | 0.000 |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | 14.340 | 2 | 0.001 |
| | | | Museum | 10.956 | 2 | 0.004 |
| | | | Regional shopping center | 117.550 | 2 | 0.000 |
| | | | Theater | 40.288 | 2 | 0.000 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | 4.419 | 2 | 0.110 |

Table 2.24. ANOVA

| | Section | Variable/Measurements | | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|---|---|
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Between Groups | 22912397787.502 | 2 | 11456198893.751 | 43.142 | .000 |
| | | | | Within Groups | 132241052230.433 | 498 | 265544281.587 | | |
| | | | | Total | 155153450017.935 | 500 | | | |
| | | Number of each destination within a 1km network buffer | Church | Between Groups | 40.387 | 2 | 20.194 | 8.573 | .000 |
| | | | | Within Groups | 1173.014 | 498 | 2.355 | | |
| | | | | Total | 1213.401 | 500 | | | |
| | | | Museum | Between Groups | 1.452 | 2 | .726 | 3.833 | .022 |
| | | | | Within Groups | 94.332 | 498 | .189 | | |
| | | | | Total | 95.784 | 500 | | | |
| | | | Office | Between Groups | 73.251 | 2 | 36.625 | 25.324 | .000 |
| | | | | Within Groups | 720.246 | 498 | 1.446 | | |
| | | | | Total | 793.497 | 500 | | | |
| | | | Regional shopping center | Between Groups | .358 | 2 | .179 | 9.428 | .000 |
| | | | | Within Groups | 9.443 | 498 | .019 | | |
| | | | | Total | 9.800 | 500 | | | |
| | | | Retail store | Between Groups | 30.539 | 2 | 15.269 | 7.270 | .001 |
| | | | | Within Groups | 1046.000 | 498 | 2.100 | | |
| | | | | Total | 1076.539 | 500 | | | |
| | | | Theater | Between Groups | 6.333 | 2 | 3.166 | 14.925 | .000 |
| | | | | Within Groups | 105.659 | 498 | .212 | | |
| | | | | Total | 111.992 | 500 | | | |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | Between Groups | 51.024 | 2 | 25.512 | 7.275 | .001 |
| | | | | Within Groups | 1746.305 | 498 | 3.507 | | |
| | | | | Total | 1797.329 | 500 | | | |
| | | | Museum | Between Groups | 22.026 | 2 | 11.013 | 5.475 | .004 |
| | | | | Within Groups | 1001.687 | 498 | 2.011 | | |
| | | | | Total | 1023.713 | 500 | | | |
| | | | Regional shopping center | Between Groups | 17.358 | 2 | 8.679 | 76.533 | .000 |
| | | | | Within Groups | 56.474 | 498 | .113 | | |
| | | | | Total | 73.832 | 500 | | | |
| | | | Theater | Between Groups | 47.960 | 2 | 23.980 | 21.375 | .000 |
| | | | | Within Groups | 558.702 | 498 | 1.122 | | |
| | | | | Total | 606.663 | 500 | | | |
| Personal Factor | Demographics/ Individual Characteristics | Education | Education | Between Groups | 28.866 | 2 | 14.433 | 7.150 | .001 |
| | | | | Within Groups | 1005.318 | 498 | 2.019 | | |
| | | | | Total | 1034.184 | 500 | | | |

Table 2.25. Homogeneous Subsets

| | Section | Variable/Measurements | | | N | Subset for alpha = .05 | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 2 | 3 |
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Not sig. | 251 | 20301.23 | | |
| | | | | Cold spot | 156 | | 30487.42 | |
| | | | | Hot spot | 94 | | | 37218.00 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | Number of each destination within a 1km network buffer | Church | Hot spot | 94 | 11.56 | | |
| | | | | Not sig. | 156 | | 12.04 | |
| | | | | Cold spot | 251 | | 12.33 | |
| | | | | Sig. | | 1.000 | .122 | |
| | | | Museum | Hot spot | 94 | 10.15 | | |
| | | | | Not sig. | 251 | | 10.27 | |
| | | | | Cold spot | 156 | | 10.30 | |
| | | | | Sig. | | 1.000 | .556 | |
| | | | Office | Hot spot | 94 | 11.59 | | |
| | | | | Cold spot | 156 | | 11.88 | |
| | | | | Not sig. | 251 | | | 12.51 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Regional shopping center | Cold spot | 156 | 10.00 | | |
| | | | | Not sig. | 251 | 10.01 | | |
| | | | | Hot spot | 94 | | 10.07 | |
| | | | | Sig. | | .464 | 1.000 | |
| | | | Retail store | Hot spot | 94 | 11.83 | | |
| | | | | Cold spot | 156 | | 12.32 | |
| | | | | Not sig. | 251 | | 12.50 | |
| | | | | Sig. | | 1.000 | .302 | |
| | | | Theater | Hot spot | 94 | 10.11 | | |
| | | | | Cold spot | 156 | | 10.37 | |
| | | | | Not sig. | 251 | | 10.41 | |
| | | | | Sig. | | 1.000 | .453 | |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | Hot spot | 94 | 13.29 | | |
| | | | | Not sig. | 251 | 13.49 | | |
| | | | | Cold spot | 156 | | 14.10 | |
| | | | | Sig. | | .370 | 1.000 | |
| | | | Museum | Cold spot | 156 | 11.78 | | |
| | | | | Not sig. | 251 | 11.95 | | |
| | | | | Hot spot | 94 | | 12.38 | |
| | | | | Sig. | | .305 | 1.000 | |
| | | | Regional shopping center | Hot spot | 94 | 10.44 | | |
| | | | | Not sig. | 251 | | 10.89 | |
| | | | | Cold spot | 156 | | 10.94 | |
| | | | | Sig. | | 1.000 | .177 | |
| | | | Theater | Cold spot | 156 | 11.11 | | |
| | | | | Not sig. | 251 | 11.19 | | |
| | | | | Hot spot | 94 | | 11.95 | |
| | | | | Sig. | | .512 | 1.000 | |
| Personal Factor | Demographics/Individual Characteristics | Income | Income | Hot spot | 94 | 6.10 | | |
| | | | | Not sig. | 251 | 6.27 | | |
| | | | | Cold spot | 156 | | 6.72 | |
| | | | | Sig. | | .287 | 1.000 | |

## 2.6. BMI Disparity: 3km Distance Weight Matrix

Table 2.26. Descriptive Statistics

| | Section | Variable/Measurements | | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Lower Bound | Upper Bound | | |
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to downtown | Not sig. | 216 | 20312.18 | 16144.79 | 1098.51 | 18146.95 | 22477.42 | 490.53 | 69188.83 |
| | | | | Hot spot | 105 | 37254.63 | 23361.66 | 2279.86 | 32733.57 | 41775.69 | 18424.66 | 118740.06 |
| | | | | Cold spot | 173 | 28319.95 | 11215.63 | 852.71 | 26636.83 | 30003.07 | 11378.46 | 67475.06 |
| | | | | Total | 494 | 26717.65 | 17754.30 | 798.80 | 25148.17 | 28287.13 | 490.53 | 118740.06 |
| | | Number of each destination within a 1km network buffer | Church | Not sig. | 216 | 12.40 | 1.97 | .13 | 12.13 | 12.66 | 10.00 | 17.00 |
| | | | | Hot spot | 105 | 11.64 | .94 | .09 | 11.46 | 11.82 | 10.00 | 15.00 |
| | | | | Cold spot | 173 | 12.02 | 1.18 | .09 | 11.85 | 12.20 | 10.00 | 15.00 |
| | | | | Total | 494 | 12.11 | 1.57 | .07 | 11.97 | 12.24 | 10.00 | 17.00 |
| | | | Museum | Not sig. | 216 | 10.24 | .43 | .03 | 10.18 | 10.29 | 10.00 | 11.00 |
| | | | | Hot spot | 105 | 10.15 | .36 | .04 | 10.08 | 10.22 | 10.00 | 11.00 |
| | | | | Cold spot | 173 | 10.34 | .48 | .04 | 10.27 | 10.41 | 10.00 | 11.00 |
| | | | | Total | 494 | 10.26 | .44 | .02 | 10.22 | 10.29 | 10.00 | 11.00 |
| | | | Office | Not sig. | 216 | 12.54 | 1.37 | .09 | 12.35 | 12.72 | 10.00 | 14.00 |
| | | | | Hot spot | 105 | 11.66 | .92 | .09 | 11.48 | 11.83 | 10.00 | 14.00 |
| | | | | Cold spot | 173 | 11.95 | 1.16 | .09 | 11.78 | 12.13 | 10.00 | 14.00 |
| | | | | Total | 494 | 12.15 | 1.26 | .06 | 12.03 | 12.26 | 10.00 | 14.00 |
| | | | Regional shopping center | Not sig. | 216 | 10.01 | .12 | .01 | 10.00 | 10.03 | 10.00 | 11.00 |
| | | | | Hot spot | 105 | 10.07 | .25 | .02 | 10.02 | 10.12 | 10.00 | 11.00 |
| | | | | Cold spot | 173 | 10.00 | .00 | .00 | 10.00 | 10.00 | 10.00 | 10.00 |
| | | | | Total | 494 | 10.02 | .14 | .01 | 10.01 | 10.03 | 10.00 | 11.00 |
| | | | Retail store | Not sig. | 216 | 12.55 | 1.53 | .10 | 12.35 | 12.76 | 10.00 | 15.00 |
| | | | | Hot spot | 105 | 11.87 | 1.20 | .12 | 11.63 | 12.10 | 11.00 | 15.00 |
| | | | | Cold spot | 173 | 12.35 | 1.48 | .11 | 12.13 | 12.57 | 10.00 | 15.00 |
| | | | | Total | 494 | 12.34 | 1.47 | .07 | 12.21 | 12.47 | 10.00 | 15.00 |
| | | | Theater | Not sig. | 216 | 10.42 | .49 | .03 | 10.35 | 10.49 | 10.00 | 11.00 |
| | | | | Hot spot | 105 | 10.13 | .34 | .03 | 10.07 | 10.20 | 10.00 | 11.00 |
| | | | | Cold spot | 173 | 10.37 | .48 | .04 | 10.30 | 10.44 | 10.00 | 11.00 |
| | | | | Total | 494 | 10.34 | .47 | .02 | 10.30 | 10.38 | 10.00 | 11.00 |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | Not sig. | 216 | 13.35 | 1.77 | .12 | 13.11 | 13.59 | 10.00 | 16.00 |
| | | | | Hot spot | 105 | 12.89 | 1.68 | .16 | 12.56 | 13.21 | 10.00 | 16.00 |
| | | | | Cold spot | 173 | 14.36 | 1.92 | .15 | 14.08 | 14.65 | 10.00 | 16.00 |
| | | | | Total | 494 | 13.61 | 1.90 | .09 | 13.44 | 13.78 | 10.00 | 16.00 |
| | | | Museum | Not sig. | 216 | 12.02 | 1.44 | .10 | 11.83 | 12.22 | 10.00 | 14.00 |
| | | | | Hot spot | 105 | 12.46 | 1.37 | .13 | 12.19 | 12.72 | 10.00 | 14.00 |
| | | | | Cold spot | 173 | 11.67 | 1.39 | .11 | 11.46 | 11.88 | 10.00 | 14.00 |
| | | | | Total | 494 | 11.99 | 1.43 | .06 | 11.87 | 12.12 | 10.00 | 14.00 |
| | | | Regional shopping center | Not sig. | 216 | 10.92 | .28 | .02 | 10.88 | 10.95 | 10.00 | 11.00 |
| | | | | Hot spot | 105 | 10.38 | .49 | .05 | 10.29 | 10.48 | 10.00 | 11.00 |
| | | | | Cold spot | 173 | 10.96 | .20 | .02 | 10.93 | 10.99 | 10.00 | 11.00 |
| | | | | Total | 494 | 10.82 | .39 | .02 | 10.78 | 10.85 | 10.00 | 11.00 |
| | | | Theater | Not sig. | 216 | 11.21 | 1.17 | .08 | 11.06 | 11.37 | 10.00 | 13.00 |
| | | | | Hot spot | 105 | 11.83 | 1.00 | .10 | 11.63 | 12.02 | 10.00 | 13.00 |
| | | | | Cold spot | 173 | 11.05 | .93 | .07 | 10.91 | 11.19 | 10.00 | 13.00 |
| | | | | Total | 494 | 11.29 | 1.10 | .05 | 11.19 | 11.38 | 10.00 | 13.00 |
| Personal Factor | Demographics/Individual Characteristics | Income | Income | Not sig. | 216 | 6.23 | 1.49 | .10 | 6.03 | 6.43 | 4.00 | 8.00 |
| | | | | Hot spot | 105 | 6.20 | 1.49 | .15 | 5.91 | 6.49 | 4.00 | 8.00 |
| | | | | Cold spot | 173 | 6.68 | 1.29 | .10 | 6.49 | 6.88 | 4.00 | 8.00 |
| | | | | Total | 494 | 6.38 | 1.44 | .06 | 6.25 | 6.51 | 4.00 | 8.00 |

Table 2.27. Test of Homogeneity of Variances

| | Section | Variable/Measurements | | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|---|---|---|
| Built. Env. | Objective Measure and Land Use | Distance to downtown | Distance to Seattle downtown | 16.473 | 2 | 491 | .000 |
| | | Number of each destination within a 1km network buffer | Church | 30.453 | 2 | 491 | .000 |
| | | | Museum | 27.851 | 2 | 491 | .000 |
| | | | Office | 32.062 | 2 | 491 | .000 |
| | | | Regional shopping center | 33.738 | 2 | 491 | .000 |
| | | | Retail store | 15.102 | 2 | 491 | .000 |
| | | | Theater | 118.286 | 2 | 491 | .000 |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | 5.492 | 2 | 491 | .004 |
| | | | Museum | .450 | 2 | 491 | .638 |
| | | | Regional shopping center | 143.091 | 2 | 491 | .000 |
| | | | Theater | 15.704 | 2 | 491 | .000 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | 6.920 | 2 | 491 | .001 |

Table 2.28. Kruskal Wallis Test

| | Section | Variable/Measurements | | Chi-Square | df | Asymp. Sig. |
|---|---|---|---|---|---|---|
| Built. Env. | Objective Measure and Land Use | Distance to downtown | Distance to Seattle downtown | 86.485 | 2 | 0.000 |
| | | Number of each destination within a 1km network buffer | Church | 9.697 | 2 | 0.008 |
| | | | Museum | 12.939 | 2 | 0.002 |
| | | | Office | 34.401 | 2 | 0.000 |
| | | | Regional shopping center | 15.393 | 2 | 0.000 |
| | | | Retail store | 14.845 | 2 | 0.001 |
| | | | Theater | 26.893 | 2 | 0.000 |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | 46.891 | 2 | 0.000 |
| | | | Museum | 20.184 | 2 | 0.000 |
| | | | Regional shopping center | 171.635 | 2 | 0.000 |
| | | | Theater | 34.846 | 2 | 0.000 |
| Personal Factor | Demographics/Individual Characteristics | Education | Education | 1.941 | 2 | 0.379 |

Table 2.29. ANOVA

| | Section | Variable/Measurements | | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|---|---|
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Between Groups | 20964571381.278 | 2 | 10482285690.639 | 38.284 | .000 |
| | | | | Within Groups | 134436436250.020 | 491 | 273801295.825 | | |
| | | | | Total | 155401007631.298 | 493 | | | |
| | | Number of each destination within a 1km network buffer | Church | Between Groups | 42.612 | 2 | 21.306 | 8.973 | .000 |
| | | | | Within Groups | 1165.914 | 491 | 2.375 | | |
| | | | | Total | 1208.526 | 493 | | | |
| | | | Museum | Between Groups | 2.463 | 2 | 1.232 | 6.617 | .001 |
| | | | | Within Groups | 91.399 | 491 | .186 | | |
| | | | | Total | 93.862 | 493 | | | |
| | | | Office | Between Groups | 64.515 | 2 | 32.258 | 21.968 | .000 |
| | | | | Within Groups | 720.991 | 491 | 1.468 | | |
| | | | | Total | 785.506 | 493 | | | |
| | | | Regional shopping center | Between Groups | .306 | 2 | .153 | 7.912 | .000 |
| | | | | Within Groups | 9.492 | 491 | .019 | | |
| | | | | Total | 9.798 | 493 | | | |
| | | | Retail store | Between Groups | 33.154 | 2 | 16.577 | 7.894 | .000 |
| | | | | Within Groups | 1031.064 | 491 | 2.100 | | |
| | | | | Total | 1064.219 | 493 | | | |
| | | | Theater | Between Groups | 6.065 | 2 | 3.033 | 14.165 | .000 |
| | | | | Within Groups | 105.119 | 491 | .214 | | |
| | | | | Total | 111.184 | 493 | | | |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | Between Groups | 167.868 | 2 | 83.934 | 25.630 | .000 |
| | | | | Within Groups | 1607.946 | 491 | 3.275 | | |
| | | | | Total | 1775.814 | 493 | | | |
| | | | Museum | Between Groups | 40.807 | 2 | 20.403 | 10.294 | .000 |
| | | | | Within Groups | 973.161 | 491 | 1.982 | | |
| | | | | Total | 1013.968 | 493 | | | |
| | | | Regional shopping center | Between Groups | 25.625 | 2 | 12.812 | 131.117 | .000 |
| | | | | Within Groups | 47.979 | 491 | .098 | | |
| | | | | Total | 73.603 | 493 | | | |
| | | | Theater | Between Groups | 41.532 | 2 | 20.766 | 18.550 | .000 |
| | | | | Within Groups | 549.650 | 491 | 1.119 | | |
| | | | | Total | 591.182 | 493 | | | |
| Personal Factor | Demographics/ Individual Characteristics | Education | Education | Between Groups | 24.255 | 2 | 12.127 | 5.965 | .003 |
| | | | | Within Groups | 998.199 | 491 | 2.033 | | |
| | | | | Total | 1022.453 | 493 | | | |

Table 2.30. Homogeneous Subsets

| | Section | Variable/Measurements | | | N | Subset for alpha = .05 | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 2 | 3 |
| Built Env. | Objective Measure & Land Use | Distance to downtown | Distance to Seattle downtown | Not sig. | 216 | 20312.18 | | |
| | | | | Cold spot | 173 | | 28319.95 | |
| | | | | Hot spot | 105 | | | 37254.63 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | Number of each destination within a 1km network buffer | Church | Hot spot | 105 | 11.64 | | |
| | | | | Not sig. | 173 | | 12.02 | |
| | | | | Cold spot | 216 | | | 12.40 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Museum | Hot spot | 105 | 10.15 | | |
| | | | | Not sig. | 216 | 10.24 | | |
| | | | | Cold spot | 173 | | 10.34 | |
| | | | | Sig. | | .093 | 1.000 | |
| | | | Office | Hot spot | 105 | 11.66 | | |
| | | | | Cold spot | 173 | | 11.95 | |
| | | | | Not sig. | 216 | | | 12.54 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Regional shopping center | Cold spot | 173 | 10.00 | | |
| | | | | Not sig. | 216 | 10.01 | | |
| | | | | Hot spot | 105 | | 10.07 | |
| | | | | Sig. | | .387 | 1.000 | |
| | | | Retail store | Hot spot | 105 | 11.87 | | |
| | | | | Cold spot | 173 | | 12.35 | |
| | | | | Not sig. | 216 | | 12.55 | |
| | | | | Sig. | | 1.000 | .236 | |
| | | | Theater | Hot spot | 105 | 10.13 | | |
| | | | | Cold spot | 173 | | 10.37 | |
| | | | | Not sig. | 216 | | 10.42 | |
| | | | | Sig. | | 1.000 | .336 | |
| | | Distance to the closest each destination within a 3km network buffer | Neighborhood/ community shopping center | Hot spot | 105 | 12.89 | | |
| | | | | Not sig. | 216 | | 13.35 | |
| | | | | Cold spot | 173 | | | 14.36 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Museum | Cold spot | 173 | 11.67 | | |
| | | | | Not sig. | 216 | | 12.02 | |
| | | | | Hot spot | 105 | | | 12.46 |
| | | | | Sig. | | 1.000 | 1.000 | 1.000 |
| | | | Regional shopping center | Hot spot | 105 | 10.38 | | |
| | | | | Not sig. | 216 | | 10.92 | |
| | | | | Cold spot | 173 | | 10.96 | |
| | | | | Sig. | | 1.000 | .235 | |
| | | | Theater | Cold spot | 173 | 11.05 | | |
| | | | | Not sig. | 216 | 11.21 | | |
| | | | | Hot spot | 105 | | 11.83 | |
| | | | | Sig. | | .188 | 1.000 | |
| Personal Factor | Demographics/Individual Characteristics | Income | Income | Hot spot | 105 | 6.20 | | |
| | | | | Not sig. | 216 | 6.23 | | |
| | | | | Cold spot | 173 | | 6.68 | |
| | | | | Sig. | | .870 | 1.000 | |

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